APPENDIX A: PUBLIC COMMENTS ON THE FIRST DRAFT PLAN FOR THE OUACHITA ROCK POCKETBOOK

FWS published notice of an opportunity to review and comment on a Ouachita Rock Pocketbook Draft Recovery Plan in the Federal Register on July 14, 1994 (Vol. 59, No. 134, pp. 35948-35949). FWS also distributed a news release inviting public review and comment to six newspapers within the range of the Ouachita rock pocketbook. FWS placed copies of the draft plan in five public libraries within the affected region, and directly distributed approximately 115 copies to various federal agency offices, state agency offices, private interests, and congressional members in the states of Oklahoma, Arkansas, and Texas. Since publication of the draft Ouachita Rock Pocketbook Recovery Plan in 1994, further information gathering on population status, tributary surveys, and related issues was completed; however, no substantive changes were made to the overall recovery strategy for the species in the final Recovery Plan.

Thirteen comment letters were received in response to the first draft plan, copies of which are included in this appendix. FWS appreciates the interest expressed by the commenting parties, and has attempted to evaluate the submitted comments in a thorough and considerate manner. FWS responses to individual comments appear both as changes in the body of the recovery plan and in a summary following the comment letters. Numbers placed in the margins of comment letters refer to specific responses appearing in the FWS's summary.

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8-10-94

To: Mr. Jerry Brabander
Mr. David Martinez

I direct my comments to you because yours were the names mentioned in article, 'Bring' em Back Alive' campaign launched for mussels, in the Broken Bow News August 17, 1994.

After consultation with a number of friends who ~~Rember~~ Remember, as I do, tragedies of the past, which we believe might continue to have an effect on many creatures of the Little River Basin. Even though these were happening of many years ago, considering the slow movement of a creature like a mussel we believe the self reintroduction would take many years. The on site observation and to the extent of the two tragedies will rest in our memories forever. The disgust we experienced when we asked for help of what we thought to be proper authorities, will also be remembered. Our efforts were quickly mingled with politics and we we were rediculed by the perpitrators for what they termed as obsticles to progress. We certainly didn't bend or break and believe our efforts did some good because the guilty parties knew we were watching.

When the Craig Fiberboard Plant four miles East of Broken Bow opened during the mid 50's the first experiment with waste dumping was to release it into a pin oak flat south of the plant the property belonging to the plant owner. Within sixty days it was obser-

1

ved the waste wasn't only killing all living creatures of the soil envolved but also the timber where it stood puddled up for any length of time. ~~Two~~ One or two settling pond were built that were filled in a short time. A relieve was made into a natural drain that entered Mountain Fork River about a quarter mile away. A friend was on the scene and took pictures which I believe he still has. Every aquatic creature was killed, the way he described it to me at the time, "Even the turtles broke their necks climbing up on rocks or running out on the bank." He came to me on that morning advising I should go see. I was buisy and told him I had already seen enough. Thad Mc Farland, Eagletown, 74734 has the pictures he took that morning and I am shure he would let anyone intrested to see them.

It is about three miles from the site of this kill to where Mountain Fork enters Little River. I know this effected this part of Mountain Fork. I am not shure of the effect on Little River. I know some of the mussels on Lower Mountain Fork have made a recovery. Especially the little white "Odie" mussel, the primary diet of sucker fish and drum. The fish themselves have also made a recovery.

About a half mile up river from the mouth of Mt. Fork is the lower end of what is know as the Nine Mile eddy. I do not recall ever seeing the mussul described further up Little River than this point. If they are, they would be in the long

2

Sholey stretch Above the Mouth of Yonubee Creek. If I was physically Able I would like to look. I would Also like to look in the stretch of Mountain Fork From the site of the Poison release, through the Doc Sherrill eddy And on up through the Huffman eddy. I believe if they were ever there they would still be there.

Thad McFarland is the owner of property At the up river end of this stretch of river From White OAK Bend, the site of th poisoning, to the U.S. highway 70 bridge on Mountain Fork, A distance by river of About three Miles. The bridge crosses At the upper end of Huffman eddy. He has had A gravel removal operation that has gone on for many year. The Fishing Along the river is wonderful, fishing in some of the dug out Ponds where gravel has been removed is Also very good. He welcoms Friends And reasonable people to Fish. Some of the Fanatics of E.P.A. have given him A hard time over the years but he believes they have come to realize they were wrong. His Property And the stretch of River up to the Re-regulation dam is A classic example where the belief by some that gravel removal And dam construction is detremental to the Aquatic creatures of the Area is A Farce. It just doesn't work that way in the little River Basin. The creatures simply move Near by And Adjust. They Are As capable of Adjusting As humans.

3

4

The other Memorable tragedy of the Little River basin was the poison spill, cresoat and penta and maybe others that entered the Rolling Fork river in 1968. This came from a post treating operation at the south west edge of De Queen Arkansas. This spill even killed vegetation along the river bank. All species of dead fish floated into the upper part of Millwood lake. A friend walked the bank of little River from the Highway U.S. 71 Bridge up to the mouth of the Cossotot River to observe the dead fish in drifts. Some one had retrieved and layed side by side on the bank, three flat head cat fish with a note, combined weight 117 lbs., There were many other species in evidence at this spot, possably by a study group of Arkansas Game and Fish. There was concern only by fishermen. The Politics of the day handeled the situation.

I spent many days walking the bank and fishing Little River. I even sampeled a stew a group of Indins living near the river south of Eagletown use to make on the river bank. I dont believe there was ever many of the mussels described, along lower little River down to Line Ford. I know the Indians called the ones I saw, (sand mussels) they didnt use them in their stew because of the sand content. The Indians name was, or is Ashalintubbi, some of the older one might shed some light on the mussel mystery.

Hope this is an assist to the mussel issue
Maybe the presentation of past history which
was so impressive and disappointing will help.

Sincerely
Eugene C. Gregory
2410 S Park Drive
Broken Bow Okla.
74728

P.S. I will gladly assist in any way.

405-584-6335

'ne McGazette Broken Bow News

AU 8 3

Letters to the Editor 1994

We Need Your help. This is simply An Unfinished Job. The Unique Nature of the Little River Basin Begs For the Project

To the Editor:

The Farm and Forestry section of the *McCurtain Gazette and Broken Bow News* July 17 presents an excellent map of the 2.7 million acre Little River Basin. This is an area unique in many ways. It is protected from the cold blasts of winter by the Kiamichi and Ouachita mountains to the north. The relative humidity of our summers during times of excessive rainfall is a tolerable blessing.

During a lifetime of hunting, fishing and just exploring, there is no end to the amazement of the biodiversity of the region. I must follow a branch or creek to the beginning to discover many, or most start with a cool spring made eternal by the hand of God.

I urge every citizen of the area who has appreciation of a thing of beauty and interest in the environment in which we live to study this map with a feeling of imagination of the hills, valleys, flora and fauna that combine to tie it together.

Take note, there are six rivers in the Little River watershed. Glover is tagged a creek on the map, but as far as I know, since the beginning of time, for those who know, it is a river not be be belittled by some I have in mind who wish to downplay its importance in the over scheme of water resources development for the Little River Basin.

There are also many beautiful creeks — Rock Creek, one of the largest, co-owned by Arkansas and Oklahoma, and one-third the size of Rolling Fork and Glover, being one of many.

Because of their vital importance to the well being of all creatures inhabiting this area, these, along with the mother, Little River itself is our golden lifeline. The upstream series of flood control dams make up the golden chain. The missing link of the golden chain to the hook at the top end of the chain is missing due to default. This hook at the end of the chain being Pine Creek on upper Little River.

When the late John Burwell arrived as one of the first forestry experts in the early '50s, he kept Mac McCartney busy for months getting acquainted with what he recognized as a fragile environment to be handled with care. He appreciated the vision of Sen. Robert S. Kerr for the vital incorporation of land, wood and water resources.

Years of honest effort, time and resources were unselfishly spent by Harold Norris, Jewel Callaham, Louie Johnson, Mayo Holman and many others working as members of the Red River Valley Association, with the cooperation of Sen. Robert S. Kerr, to make a complete golden chain of upstream dams designed for flood control and recreation a reality in the Little River Basin.

Long ago, I asked the chief of Corps of Engineers officer in charge during the planning stage for the upstream dams,and it became likely the construction of the Glover Dam would be delayed. What part would the Glover Dam play in the overall scheme of flood control dams? He presented a map and explained to the best of my memory: "During flood stage on the rivers of the area, Glover would contribute about 15 percent of flood waters to be controlled. This would be from 8 to 15 feet of flood water on the upper Little River system.

The lack of control on Glover would greatly affect bank stabilization on Little River below where it enters the river and the sedimentation would also be a negative factor.

I, along with all who have observed have watched the deterioration of the bank and sedimentation as predicted come to pass. Some of the old camping spots, especially in river beds, have caved into the river. This is an ongoing tragedy. Many of the floods on Glover are very quick to materialize and very swift. This has the effect of a cutting torch on the river banks.

The default and delay in construction of Glover Dam and the reality of a permanent pool of water where the river free flow is controlled only during flood stage was caused by dater mania by a small group of fanatics who imported a copy cat lie from the Tennessee River Valley where the small darter had been declared to be endangered. They didn't know the leopard darter existed until they were introduced by those who had used them for live bait for bass fishing for many years.

The snail darter was declared to be prospering and well where they had always been last year. They had never been endangered and were removed from the list.

The leopard darter is alive and prospering in its chosen habitat and has never been endangered. It's time to demand this obstacle to progress be removed.

At least one candidate for governor knows the true story of the issue and has promised help in the past. We need the commitment of others. I will assure our congressional delegation is listening.

The congressional approval of the dam on Glover River must not be removed as some selfish groups seek. A progressive future of those who call southeastern Oklahoma home should be the primary consideration in the development of our God given natural resources. Planning must have the needs of the future in mind.

If further impact study is required, all that need to be done is to look to the benefits the permanent pool on Rolling Fork River near DeQueen, Ark., has afforded since completion about 20 years ago.

Those responsible for the default in the construction of the congressionally approved dam on Glover are liable. An outfit who claims to have 14,000 members around the state of Oklahoma should have liability insurance enough to cover the cost of construction. If not, their resources should be pooled for political clout, as it has been used in the past. We will cooperate.

The people of McCurtain County should demand the final link to the golden chain. We should let it all hang out during this election year.

The 15 percent help that would be afforded by Glover Dam is needed by Larry Pratt and many others who are watching as the bank of Little River cave in. This is their soil that is causing the siltation and gradual filling of holes of water along the river.

We need help to make McCurtain County the garden spot of Oklahoma. I promise to continue to do my part.

Sincerely yours,
E.C. "Cotton" Gregory

P.S. I will answer any question anyone wished to present in writing with a self-addressed stamped envelope.

Texas Department of Transportation

DEWITT C. GREER STATE HIGHWAY BLDG. • 125 E. 11TH STREET • AUSTIN, TEXAS 78701-2483 • (512) 463-8585

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August 31, 1994

Mr. Jerry J. Brabander
Field Supervisor
U.S. Fish and Wildlife Service
Ecological Services
222 S. Houston, Suite A
Tulsa, OK 74127

Dear Mr. Brabander:

Thank you for the opportunity to review and comment on the Draft Ouachita Rock-pocketbook Recovery Plan (Plan). We have these comments:

> Please use the abbreviation TxDOT to refer to the Texas Department of Transportation in the plan. 5
>
> TSDH (TxDOT) is scheduled for an estimated $2000 contribution in each of three years for cooperative projects to increase restoration and protection of degraded habitat and populations (Page 79, Implementation Schedule, Task number 3.22 under responsible party). How was this contribution determined? 6

We have asked our Paris, TX, district to compile a list of all projects planned within the drainages potentially occupied by this mussel (Howells 1993) so that we may plan appropriate actions. We will consult with the Arlington, TX office of USFWS for this species, unless otherwise instructed. 7

We look forward to constructive planning to ensure that our actions are not detrimental to any of the stream fauna.

Sincerely,

For Dianna F. Noble, P.E.
Director of Environmental Affairs

An Equal Opportunity Employer

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TEXAS
PARKS AND WILDLIFE DEPARTMENT
4200 Smith School Road • Austin, Texas 78744 • 512-389-4800

Heart of the Hills Research Station
HC07, Box 62
Ingram, TX 78025
1 September 1994

Jerry J. Brabander
U.S. Fish and Wildlife Service
Ecological Services
222 S. Houston, Suite A
Tulsa, OK 74127

Dear Sir:

I recently received and read the draft Recovery Plan for Ouachita rock-pocketbook (Arkansia wheeleri). I find it well put together and have few comments. Martinez did an excellent job. Several points worth mentioning include:

(1) Page 8; collections of Arkansia in Texas:

- Aside from the specimen taken by J.A.M. Bergman in Pine Creek, Lamar Co., TX, a second specimen was found by C.M. Mather and J.A.M. Bergman on 8 August 1993 in adjacent Sanders Creek some distance below Pat Mayse Reservoir (USACE reservoir), Lamar Co., TX. The second individual was also relatively-recently dead. 8
- On 8 and 9 August 1993, C.M. Mather (University of Science and Arts of Oklahoma), J.A.M. Bergman (Boerne, TX), along with myself, Vernon Hodges, and Jarret Marquart (TPWD, HOH, Ingram, TX) surveyed areas on both Pine and Sanders creeks, Lamar Co., TX, and Crook Lake on Pine Creek. No additional Arkansia specimens were found.
- On 13 June 1994, Tony Castillo and Jarret Marquart (TPWD, HOH) surveyed areas on Pat Mayse Reservoir and Crook Lake primarily seeking local mapleleafs (Quadrula spp.) and pink papershell (Potamilus ohiensis) for electrophoretic analysis here. High water conditions prevented sampling Sanders and Pine creeks and confounded efficient sampling of the impoundments. No Arkansia were found.
- During the week of 8 August 1994, Caryn Vaughn (Oklahoma Natural Heritage Inventory) and her staff along with Mather and Bergman again attempted to sample Pine and Sanders creek as well as Bois de Arc Creek to the west. However, again high water thwarted successful sampling. Neither Vaughn (pers. comm.) nor Bergman and Mather (pers. comm.) found Arkanisa.

(2) Page 15; Impoundments and Channelization:

Pat Mayse Reservoir was constructed long before Arkansia was found in Sanders Creek; the reservoir occupies much of that short system. During the 8 August 1993 survey of Sanders Creek below Pat Mayse Reservoir, virtually all discharge from the dam had been stopped leaving the creek with little or no flow. Heavy rock rubble has been placed below the dam, presumably to protect from scouring discharges that likely occur at other times. Survival of the benthic community downstream can likely be enhanced by suggesting minimum and maximum water releases. Because 9 the reservoir is fairly large and the creek below small and short, low-volume minimum releases could prevent water stagnation and could likely be easily accomplished with little disruption to general reservoir operation. Our general mussel survey work in rivers below reservoirs in Texas typically indicated most impoundment operators are completely oblivious to environmental impact of discharged (or non-discharged) waters.

Hopefully the above comments will be useful in completing your recovery plan. If I can help in any way, please do not hesitate to ask.

Sincerely,

Bob Howells

Bob Howells

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PARKS AND WILDLIFE DEPARTMENT
4200 Smith School Road • Austin, Texas 78744 • 512-389-4800

September 6, 1994

Mr. Alan David Martinez
U.S. Fish and Wildlife Service
222 South Houston, Suite A
Tulsa, OK 74127-8909

Dear Mr. Martinez:

I have reviewed the draft recovery plan for the Ouachita rock-pocketbook, Arkansia wheeleri, that you recently prepared. Overall, I thought the draft recovery plan to be well written, and I haven't any substantive comments on the bulk of the text. However, you may be 10
interested to know that in addition to Bergman's collection from Pine Creek (pg. 8), a recently dead shell of Arkansia wheeleri recently was found in nearby Sander's Creek. This small stream also is in Lamar County, Texas and is a tributary of the Red River. This information was given to me by Bob Howells of our Department who is responsible for mussel research in our state. Bob can be reached at: Texas Parks and Wildlife Dept., Heart of the Hills Research Station, HC-7, Box 62, Ingram, TX 78025, (210) 866-3356. Both Pine and Sanders creeks 11
subsequently have been designated as no-harvest mussel sanctuaries by our Department which will afford some protection for any existing populations. You may wish to reflect these changes in your draft plan where appropriate. If I can provide you further assitance on this matter, please don't hesitate to ask.

Sincerely,

Dr. David E. Bowles
Endangered Species Biologist

United States Department of Agriculture **Forest Service** **Ouachita National Forest** **P. O. Box 1270 Hot Springs, AR 71902**

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Reply to: 2670

Date: September 8, 1994

Mr. Jerry J. Brabander, Field Supervisor
U.S. Fish and Wildlife Service
Ecological Services
222 South Houston, Suite A
Tulsa, Oklahoma 74127-8909

Dear Mr. Brabander:

We have reviewed the draft Ouachita Rock-pocketbook Recovery Plan and find it to be a thorough plan. We stand ready to assist where we can and as funding permits.

As you probably are aware we have worked with your office and Dr. Caryn Vaughn, **12**
of the Oklahoma Natural Heritage Inventory to finance a Challenge Cost Share project to complete mussel surveys on the Tiak Ranger District covering major tributaries to both the Red and Little Rivers. The final report of that project is not due until December 31, 1994. Your office will be provided a copy upon our receipt of the report. It is our understanding that no Ouachita rock-pocketbook mussels were found in the tributaries. This probably completes our responsibility for task 2.3.

We are also interested in cooperating in life history/genetic or other similar **13**
type studies utilizing our Challenge Cost Share Program for funding of small short-term projects as the opportunities arise and our funding allows. Please forward us any such proposals that you may be unable to fund for our consideration.

Thank you for the opportunity to review this draft. We look forward to working with you in implementing these actions.

Sincerely,

RICHARD W. STANDAGE
for
LARRY D. HEDRICK
Staff Officer, Fisheries, Wildlife, T&E and Range

cc: M. Bosch, R8
District Rangers, Tiak, Kiamichi, & Choctaw w/ Draft Recovery Plan

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Oklahoma Biological Survey

Oklahoma Natural Heritage Inventory

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8 September 1994

Jerry L. Brabander, Field Supervisor
U.S. Fish and Wildlife Service
222 S. Houston, Suite A
Tulsa, Oklahoma 74127-8909

Dear Mr. Brabander:

I have reviewed the draft Ouachita Rock Pocketbook Recovery Plan. The plan is well-written and designed. When implemented it should aid in the recovery of *Arkansia wheeleri*. Specific comments are listed below. These comments are submitted on behalf of myself and the Oklahoma Natural Heritage Inventory.

1. Executive Summary, under Current Status. Need to add that we now know of an existing small population in the Little River in Oklahoma. 14

2. Page 3, 2nd paragraph. In the Little River *A. wheeleri* is more easily confused with *Amblema plicata* than with *Quadrula pustulosa*. 15

3. Page 7, 3rd paragraph. An additional location for *A. wheeleri* in the Kiamichi River was found by myself in August 1993. Two live individuals were found in a large mussel bed immediately above where the Kiamichi River becomes Lake Hugo. 16

4. Page 8, 2nd paragraph. In 1994 myself and assistants surveyed the Little River from I-70 to the mouth of the Mountain Fork River. Single live *A. wheeleri* were found at two sites. Survey efforts on the Little River are not complete. Weather permitting, we will survey from the mouth of the Mountain Fork to the Rolling Fork River in Arkansas during mid to late September, 1994. 14

5. Page 11, top of page. The habitat associations listed here are from a preliminary report from 1992. A more accurate habitat description, extracted from Vaughn et al. (1993) is given below: 17

"*Arkansia wheeleri* occurs in both pools and backwaters in the Kiamichi River, not just backwaters as was previously believed. However, while pool and backwater habitats are common in the Kiamichi River, *A. wheeleri* only occurs in a select few of them. Pools and backwaters where *A. wheeleri* occur have in common an (1) abundant and diverse assemblage of mussels, (2) bottom substrata that are stable and contain adequate amounts of fine gravel/coarse sand, (3) low current (but not stagnant), (4) low siltation, and (5) proximity to tributaries, emergent vegetation, riffles and gravel bars.

Although pools and backwaters were considered different habitat types in this study, in most cases they are tightly interconnected and share many characteristics in common. Backwater areas tend to be shallower and have finer substrata. As backwaters merge into the main river channel they turn into deeper pools with coarser substrata and slightly higher current velocity. As stated before, at our sites *A. wheeleri* occurred in both of these microhabitats. In addition we believe *A. wheeleri* moves back and forth between these habitats either voluntarily or through physical displacement of shifting sediments. As described in the Results section, individuals at site three that were repeatedly recaptured had not moved. However, at another site (site five) we found unmarked individuals in the backwater area only for two years (1990 and 1991), and then in the pool area alone in 1992. At this site the backwater and pool were interconnected. This site had undergone a great deal of sediment deposition during the high flow of spring 1992 and a great deal of the original backwater sediment was shifted to the pool area.

Recent studies addressing the substratum preferences of unionids have reached different conclusions and substratum preferences among unionids remain poorly understood. However, mussels are generally believed to be most successful in stable, sand-gravel mixtures and are generally absent from substrata with heavy silt loads (Cooper 1984, Salmon and Green 1983, Stern 1983, Way et al. 1990). Most unionid species can be found on a number of different substrata, but growth rates of individuals in each microhabitat can be quite different (Kat 1982, Hinch et al. 1989). Furthermore, many mussel species can occupy a wide range of habitats as a result of extensive larval dispersal over a heterogenous stream environment (Strayer 1981), but growth and reproduction may be optimized only under the habitat conditions described above. As an example consider *Amblema plicata*, the clearly dominant mussel species in the Kiamichi River. This species occurred in every microhabitat we examined (pool, backwater, riffle, run) and at every site we examined. Its density, however, was not the same in all of these habitats. The greatest numbers of individuals were found in the large, diverse mussel beds where *A. wheeleri* also occurred. It is clearly able to "survive" in a large number of habitats, but its survival and growth is only optimized in "good" habitat (Strayer 1981).

The key to the distribution of *A. wheeleri* in the Kiamichi River is the presence of the large mussel beds where other mussel species thrive. These shoals represent optimal habitat for most mussel species, as evidenced by the large number of species and their high abundance. These shoals usually contain both pool and backwater areas,

Oklahoma Natural Heritage Inventory comments

have significant gravel bar development with accompanying vegetation (dominated by *Justicia americana*), and are close to a tributary (usually within one quarter mile). Shoals are usually adjacent to a major riffle area, although they can be either up or downstream of the riffle.

While other mussel species may survive in less than optimum habitat, *A. wheeleri* clearly cannot. They only survive in the best available habitat. Other studies have shown that these mainstream river shoals in shallower areas with slow, steady current and vegetation and coarse substrate are optimal habitat for lotic unionids because of minimal turbulence, low silt and steady food supply (Salmon and Green 1982).

In summary, *A. wheeleri* does not show a habitat preferences that is unique from other unionids in the Kiamichi River. However, *A. wheeleri* only occurs in the best available habitat for mussels."

In addition, I have recently completed some additional analyses of A. wheeleri ecological associations. These are detailed in the following manuscript: Vaughn, Caryn C. and Mark Pyron. Population Ecology of the Ouachita Rock Pocketbook Mussel, *Arkansia wheeleri* (Bivalvia: Unionacea), in the Kiamichi River, Oklahoma. this manuscript is currently in review for the *American Malacological Bulletin*. I have enclosed a copy.

6. Page 11, bottom of first paragraph. The fact that Vaughn and Pyron (1992) did not find *A. wheeleri* in "muddy or silty" substrates like other surveys has to do with how one defines a substrate type. We actually measured substrate particle sizes using standard USGS techniques. Using this methodology, the finest substrate that *A. wheeleri* occurred in would have been sand, and we report this habitat association in Vaughn and Pyron (1992) and Vaughn et al. (1993). This sandy substrate type is the prevalent one in shallow backwaters where Wheeler (1918), Isely (1925) and Clarke (1987) did their sampling. They refer to this sand as "muddy and silty" but they did not measure particle sizes, and according to USGS standards it would be sand. I found no areas in the Kiamichi River that geologically could be defined as silt that contained mussels. 18

7. Page 12, 2nd and 3rd paragraphs. The following material from Vaughn et al. (1993) should be incorporated: 19

"Because of its rarity, the reproductive biology of *A. wheeleri* remains unknown. Like other anodontines, it is probably bradytictic. The closest relative of *A. wheeleri*, *Arcidens confragosus*, becomes gravid in the fall and releases glochidia in the spring (Clarke 1981). We were unable to obtain any gravid *A. wheeleri* and thus obtained no glochidia. *A. wheeleri* glochidia are probably similar to other alasmidontine

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glochidia. Alasmidontine glochidia are asymmetrical and have a stylet covered with microstylets which facilitate attachment to the fish host. Glochidial releases are probably tied to natural water temperature changes in the spring and fall (Jirka and Neves 1992).

The fish host or hosts of *A. wheeleri* remain unknown. However, we have identified strong possibilities for the fish host species. *A. wheeleri* was positively associated with several cyprinid species which were found to harbor glochidia. *Notropis (=Lythrurus) umbratilis*, the redfin shiner, inhabits "sluggish pools lined with water willows (*Justicia americana*) over gravel or sand substrates" (Robison and Buchanan 1988). This is the same habitat occupied by *A. wheeleri*. *N. umbratilis* is widespread in the Mississippi and Ohio valleys and in the southern Great Lakes tributaries as far north as western New York, southern Ontario, southern Michigan and Wisconsin, and southeastern Minnesota. It occurs south in the Mississippi valley to the Red River drainage but is uncommon in tributaries east of the Mississippi River. It occurs west to central Kansas and Oklahoma in the Missouri, Arkansas and Red River drainages."

Notropis suttkusi, a new species of cyprinid from the Ouachita uplands of Oklahoma and Arkansas, was recently described by Drs. Julian Humphries at Cornell University and Robert C. Cashner at the University of New Orleans (Humphries and Cashner 1994). The range of *N. suttkusi* is from the Blue River throughout the Little River drainage, and includes the Kiamichi River (R.C. Cashner, pers. comm.). The taxonomy of the species in the Ouachita River is unresolved (R.C. Cashner, pers. comm.).

8. Page 14, first paragraph. Please see the discussion of factors affecting mussels in: Mehlhop, Patricia and Caryn C. Vaughn. 1994. Threats to and sustainability of ecosystems for freshwater mollusks. Pp. 68-77 in Covington, W. and L.F. Dehand (eds)., Sustainable Ecological Systems: Implementing an Ecological Approach to Land Management. General Technical Report Rm-247 for Rocky Mountain Range and Forest Experimental Station. U.S. Forest Service, U.S. Department of Agriculture, Fort Collins, CO. 363 pp. A copy of this paper is attached.

9. Page 16, second paragraph. The current data from the Little River back up this 20
statement. While relict shells of *A. wheeleri* occur throughout the lower reaches of the river, live specimens have only been found in the mussel beds that are the furthest away from Pine Creek Reservoir.

10. Page 17, 2nd paragraph. Like Clarke (1987), in our surveys this summer we 21
also found that mussel diversity improves dramatically the closer one gets to the confluence with the Mountain Fork River (above Broken Bow) and away from Pine Creek Reservoir. We have also found that the mussel beds near the confluence with

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the Mountain Fork are healthier; that is, they contain fewer dead specimens than those near Pine Creek Reservoir. We are presently in the process of quantifying this by counting the number of dead versus live shells in each quadrat that we sample in the Little River. Mussel populations below Pine Creek Reservoir are not doing well and cold water from Pine Creek Reservoir is certainly part of the problem. Effluent from the paper mill at Wright City is also a factor.

We have not yet sampled in the Little River below the confluence with the Mountain Fork River. These data will be collected shortly and will be made available to the U.S. Fish and Wildlife Service as soon as they are collected. We will be looking at shell size distributions to see if there have been any effects of the cold water discharge from Broken Bow Reservoir on mussel size distributions. This will allow us to make inferences about recruitment. Mussels are long-lived organisms and one cannot tell if a population is doing well by simply looking at diversity and abundance. You could have a diverse, old population that is managing to hang on but is not reproducing. Such a population will eventually go extinct.

11. Page 19, top of page. Please add the following material from Vaughn et al. 22
(1993):

"It appears that historically *A. wheeleri* did equally well above and below Jackfork Creek (Clarke 1987). Historically, *A. wheeleri* occurred at least seven sites between Clayton and Antlers. However, in five years of combined sampling effort by Mehlhop and Miller, 1988-1989, and ourselves,1990-1992, we have only found three subpopulations of *A. wheeleri* below Jackfork Creek. Therefore, only three out of seven or 43% of the known subpopulations of *A. wheeleri* survive below Jackfork Creek. In contrast, three out of four or 75% of the historical locations of *A. wheeleri* above Jackfork Creek have been confirmed and five new locations have been discovered (Mehlhop and Miller 1989, Vaughn 1991). The fourth historical location above Jackfork Creek has not been adequately surveyed and may well contain a subpopulation of *A. wheeleri*. This site cannot be surveyed because of threats from a landowner along the river. One new location was discovered directly above the top of Hugo Reservoir in August, 1993. In addition, the relative abundance of *A. wheeleri* is slightly higher above Jackfork Creek than below. Unfortunately, we have no historical abundance data for *A. wheeleri* in the Kiamichi River.

Overall mussel densities vary both above and below Sardis Reservoir and relative abundances of most mussel species are not significantly different above and below the reservoir. However, in any mussel survey it is easier to find large adults than small, secretive juveniles. As shown above with the *A. wheeleri* data, most adult mussels were probably produced before the reservoir was filled. Therefore, a finding of no differences in relative abundances of adult mussels above and below the

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reservoir may actually be a reflection of habitat conditions before reservoir construction. To determine the effects of Sardis Reservoir on the recruitment of mussels in the Kiamichi River we examined the size distribution of *Amblema plicata*. *A. plicata* is a generalist mussel species that is extremely abundant in the Kiamichi River and occurred at all of our sites. Many juvenile mussels are extremely difficult to identify to species, but juvenile *A. plicata* are readily identifiable. Shell lengths of live *A. plicata* from above Sardis reservoir were significantly different than shell lengths of live *A. plicata* from below the reservoir. These data indicate that recruitment of *A. plicata* is reduced below Sardis Reservoir. Smaller *A. plicata* were much more common above Sardis Reservoir than below. Because *A. plicata* is a common, tolerant species, any reductions in its recruitment may signify similar problems with most mussel species in the community.

Recently malacologists have voiced concerns that many North American unionid 23
populations are composed of slowly dwindling numbers of long-lived adults destined for extirpation as pollution and other disturbances prevent juvenile recruitment to aging populations (McMahon 1991). The lowest average number of glochidia found in the drift occurred at sites 4 and 5, the two sites below and closest to the confluence with Jackfork Creek.

To date we have found no water chemistry differences at sites above and below Sardis Reservoir. However, this study was designed to gather broad information on river habitats used by *A. wheeleri* and is not an intensive investigation of water quality dynamics in proximity to Jackfork Creek. Nevertheless, we have observed large 24
physical differences in water level and flow regime fluctuations above and below Sardis Reservoir. For example, site 4 (Clayton) is almost directly below the confluence with Jackfork Creek. The measured summer flow rates at this site are typically much higher than the other sites because of water being released from the reservoir. Periodic scouring of substrata exposed to high flow velocities can remove both substrata and mussels and prevent their successful resettlement (Young and Williams, 1983; McMahon, 1991). When we visited site 7 during the summer of 1991 water levels had obviously just dropped drastically. Our evidence for this was the large number of small pools on gravel bars that harbored live but rapidly perishing fish and mussels. We counted over 100 stranded mussels at this site. Water level variation can have significant effects on mussel survival and may pose a significant threat to *A. wheeleri* at sites below the confluence of Jackfork Creek. Declining water levels expose relatively immotile mussels for weeks or months to air. It is doubtful that *A. wheeleri* can withstand such long air exposure, especially during the hot southeastern Oklahoma summer. Water temperature in some of the pools of stranded animals exceeded 35^{0}C. Adult mussels are fairly sedentary in habit. While most species are adapted to seasonal changes in water levels and flow rates, they cannot

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move fast enough to respond to unpredictable and rapid changes in water level and flow rate.

Rivers regulated by dams differ from free-flowing rivers in many ways and alteration in volume of flow and timing of discharge can seriously impact riverine fauna. Stream organisms, including mussels, have evolved in rivers that experience seasonal low-flow and high-flow periods (Meador and Matthews 1992). Fluctuating flows, especially if there will be lower flows for long periods to time, will result in the stranding of many mussels. Unlike fish species which can move rapidly in and out of microhabitats with changes in water levels, mussels move very slowly and are unable to respond to sudden drawdowns. Even if stranding doesn't actually kill a mussel, desiccation and thermal extremes will cause physiological stress and may reduce reproductive potential (McMahon 1991). We have already observed significant stranding of mussel individuals in the Kiamichi River below Sardis Reservoir (Vaughn and Pyron 1992).

Fluctuating flows also mean that transport of particulates will vary. Depending on the 25
flow schedule and the materials normally transported in the water column, there is the potential for loss of organics which are the food base for mussels.

Increased flows associated with river regulation have the potential to alter the 26
distribution of sediment through scour, flushing, and deposition of newly eroded materials from the banks. Increased flows have the potential to activate the bed (i.e. actually cause the bottom of the river to move). Bedload movement will wreak havoc on the survival of many mussels, particularly juveniles (Young and Williams 1983). Erosion caused by increased flows at one location results in deposition of this material further downstream. This "zone of aggradation" results in an increased width/depth ration of that portion of the channel. As width/depth ratios increase the potential for bedload transport also increases. Thus, increased flows cause habitat loss through both sediment deposition and increased bed mobility.

Sediment deposition not only removes habitat, but also clogs mussel siphons (i.e. smothers them) and interferes with feeding and reproduction (Aldridge et al. 1987).

In the long term, higher base flow levels and shorter periods between peak flood 27
periods will decrease habitat complexity by preventing the formation of islands, establishment of macrophyte beds etc... (Frissell 1986). Stabilized sediments, sand bars, and low flow areas, are all preferred unionid habitats (Hartfield and Ebert 1986, Payne and Miller 1989, Stern 1983, Way et al. 1990). It is around these "complex" areas that most mussel beds in the Kiamichi River, and indeed the highest diversity of stream fauna, are found.

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Flow regulation not only has the potential to profoundly effect the stream fauna, but 28
riparian fauna as well. Flood waters that normally recharge soils and aquifers may be rapidly exported downriver. Lowered water tables may cause shrinkage of the riparian corridor and shifts in terrestrial species composition (Allan and Flecker 1993, Smith et al. 1991).

Because of their dependence on the appropriate substrate and flow conditions, 29
freshwater mussels, including *A. wheeleri*, are already naturally patchily distributed in rivers. Any further fragmentation, such as the construction of a reservoir, will act to increase patchiness and to increase the distance between patches. These effects may have major consequences for the metapopulation (i.e. local or subpopulations connected by infrequent dispersal) structure of *A. wheeleri* (Vaughn 1993b). As some subpopulations are eliminated and dispersal distances are increased between other subpopulations, demographic and genetic constraints will diminish the ability of this species to respond to even natural stochastic events much less human-induced environmental change (Wilcox 1986, Murphy et al. 1990).

Timber harvesting operations can have significant effects on both stream water 30
quantity and quality. The influence of catchment vegetation on stream discharge is dependent on a large number of variables, many of which are site-specific. However, in general, removal of forest vegetation increases stream runoff (Campbell and Doeg 1989) and leads to many of the effects of increased flows discussed above.

Road-building activities and low water crossings associated with logging can lead to 31
the development of "headcuts", or migrating knickpoints in the channel remote from areas of actual modification. Headcuts result in severe bank erosion, channel widening, and depth reduction and can have devastating effects on the mollusc fauna (Hartfield 1993).

12. Page 20. The following is also from Vaughn et al. (1993):

"Their sedentary life style and filter-feeding habits make mussels especially 32
vulnerable to chemical pollution events. Contaminants can destroy mussel populations directly by exerting toxic effects or indirectly by causing or contributing to the elimination of essential food organisms or host fish (Havlik and Marking 1987). To date, the Kiamichi River has remained relatively unpolluted, and this is one reason it maintains a generally healthy mussel fauna. Rivers near the Kiamichi, which have experienced more development, are rapidly losing their mussel faunas. For example, below the point where the Little River receives effluent from a paper mill, there have been massive mussel die offs.

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Natural predation does not appear to be a threat to *A. wheeleri* in the Kiamichi River. **33**
Fresh shells found opened along the shore are predominately *Corbicula* (Vaughn and Pyron, pers. obs.). *Corbicula* have been shown to be the dominant prey of muskrats in other systems in which it has invaded (Neves and Odum 1989).

Zebra mussels (*Dreissena polymorpha*) are now found in the Arkansas River system **34**
in Oklahoma. The high dispersal capabilities of this species make it highly probable that it will invade the Red River system in the near future (French 1990). Invasion of the Kiamichi would most likely be from the two existing reservoirs, Sardis and Hugo, because this is where boats (with encrusted adults or water containing larvae) would be launched. The zebra mussel could then spread downstream from both reservoirs. Construction of the authorized Tuskahoma Reservoir would provide an additional entryway for zebra mussels into the Kiamichi. The exotic bivalve *Corbicula fluminea* may also pose a threat to *A. wheeleri* (Mehlhop and Miller 1989)."

13. Page 35. At the present time releases from Sardis Reservoir are from the **35**
surface and are warm. If cold, hypolimnetic releases were initiated these would threaten the *A. wheeleri* population downstream of Jackfork Creek.

14. Page 44, task 1.31. On-site population monitoring should include an assessment **36**
of current landuse immediately adjacent to and upstream of the site and a measure of riparian thickness and health.

15. Page 54, task 4.1.

Identification of the fish host might best be done by a molecular genetic approach **37**
(DNA fingerprinting). Such analyses are being used by other researchers to identify fish hosts of mussels (White 1993). The technique compares DNA obtained from glochidia found attached to fish to a battery of DNA's from adult mussels in the community. Even this approach would not guarantee identification of the fish host. Identification is contingent upon *A. wheeleri* still reproducing (unknown), fish being collected during the spawning season of *A. wheeleri* (unknown), and collection of the correct fish host (unknown). We have tissue of three *A. wheeleri* from the Kiamichi River stored in an ultracool freezer at the University of Oklahoma. This material could be made available to researchers for DNA fingerprinting once they work out the techniques on more common species. We also have preserved glochidia samples available for analysis.

16. Page 56, task 5.2. How will juveniles for such a study be obtained? Juveniles of **38**
most species of mussels, probably including *A. wheeleri*, are extremely difficult to tell apart. Juvenile *A. wheeleri* in the Kiamichi River are probably indistinguishable from

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juvenile *Quadrula pustulosa* until they reach a certain size. In order to be able to carry out this task you will have to have a successful culture program.

17. Page 57, task 5.3. As written, I am not sure exactly what this means. I have already done a great deal of work comparing areas with and without *A. wheeleri* (see Vaughn et al. (1993) and attached manuscript by Vaughn and Pyron). Comparing areas with mussels to areas with no mussels at all would not yield much usable information. Please see recent articles by Strayer (1993), Strayer et al. (1994) and Strayer and Ralley (1993). **39**

18. Page 62, task 9.1, last sentence. How will this be achieved under the confines of the Freedom of Information Act? **40**

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Thank you for allowing me to review the plan.

Sincerely,

Caryn C. Vaughn

Caryn C. Vaughn, Ph.D.

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Population Ecology of the

Endangered Ouachita Rock Pocketbook Mussel,

Arkansia wheeleri (Bivalvia: Unionacea),

in the Kiamichi River, Oklahoma

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Running head: Ouachita Rock Pocketbook Mussel in the Kiamichi River

Keywords: Unionacea, ecology, endangered species, Arkansia wheeleri

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ABSTRACT

The only known remaining viable population of Arkansia wheeleri in the world occurs within a 128 km stretch of the Kiamichi River in Pushmataha County, Oklahoma. Within this river A. wheeleri occurs only within the most species-rich mussel beds. In its optimal habitat, A. wheeleri is always rare: mean relative abundance varies from 0.2 to 0.7% and the average density is 0.27 individuals/m^2. The youngest individual A. wheeleri encountered was approximately 12 years of age. Forty-three percent of the historically known subpopulations of A. wheeleri below where inflow from an impounded tributary enters the Kiamichi River have apparently been extirpated, and no new subpopulations have been located. A. wheeleri survive at 75% of the historically known locations above the impounded tributary and five new subpopulations have been located.

INTRODUCTION

Arkansia (syn. Arcidens) wheeleri (Bivalvia: Unionacea), the Ouachita Rock Pocketbook Mussel, is a federal endangered species (Federal Register 56(205):54950-54957). Originally named Arkansia wheeleri by Ortmann and Walker (1912), Clarke (1981, 1985) recognized Arkansia as a subgenus of Arcidens. The species is considered by Clarke to be distinct. However, Turgeon et al. (1988) have continued to use the binomial Arkansia wheeleri.

The historical distribution of Arkansia wheeleri was in the Ouachita and Little Rivers in Arkansas and the Kiamichi River in Oklahoma, all south-flowing rivers out of the Ouachita Mountains (Figure 1). A survey by Clarke (1987) indicated that the species is probably extirpated from the Ouachita River and severely depleted in the Little River in Arkansas. In 1992 and 1993, relict shells of A. wheeleri were found in the Little River in Oklahoma below Pine Creek Reservoir (Vaughn, 1993a).

Arkansia wheeleri was first reported from the Kiamichi River by Isely (1924) who conducted a survey of the river in 1911. Clarke (1987) and Mehlhop and Miller (1989) both conducted recent status surveys for A. wheeleri in the Kiamichi River. They found that A. wheeleri was patchily distributed and rare in the Kiamichi River from above Hugo Reservoir to Whitesboro (Figure 2). Since the construction of a dam and reservoir in the lower reaches of the Kiamichi in the 1970s, some of the backwater areas where it was known to occur have been destroyed (Valentine and Stansbery, 1971), and connection with potential habitats on the Red River and other tributaries to it has been blocked. Based on the above information A. wheeleri was listed as endangered in October, 1991 (Federal Register 56:54950-54957)

The objectives of this study were to determine the distribution and abundance of Arkansia wheeleri in the Kiamichi River, characterize the species' microhabitat, and determine movement, growth, and survivorship of individuals. We also examined the impact of a reservoir on the A. wheeleri population.

STUDY SITE

The Kiamichi River is a major tributary of the Red River. It flows for a total of 180 km through a 4,800 km^2 drainage area across the Ridge and Valley Belt of the Ouachita Mountain geologic province and the Dissected Coastal Plain province (Curtis and Han, 1972). The average gradient of the river is 0.47 m/km. Two reservoirs influence the river: Sardis Reservoir is an impoundment of Jackfork Creek, a tributary of the Kiamichi River. Hugo Reservoir is an impoundment of the lower Kiamichi River. The vegetation cover in the watershed can be described as a patchwork of forest made up of short-leaf and loblolly pine, mesic oak forests, and diverse bottomland habitats in various stages of maturity. Another large component of the watershed coverage is made up of pasture and other agricultural lands (Vaughn et al., 1993).

The Kiamichi River is located near the western edge of mussel diversity in the United States (Williams et al., 1992; Warren and Burr, 1994). Therefore, because of historical biogeographic factors, one would not expect diversity in the Kiamichi River to be as high as rivers in more eastern states. Nevertheless, the Kiamichi River has high mussel diversity for its size and geographic location. Fifty-five species of mussels are known from Oklahoma (Williams et al., 1992), and twenty-nine of these currently occur in the Kiamichi River (Vaughn et al., 1993). Only two species that were known historically from the Kiamichi River (Isley, 1924) no longer occur there. Several species of mussels from the Kiamichi River are endemic to rivers in the Ouachita Mountains, including Arkansia wheeleri, Ptychobranchus occidentalis (Conrad) and Villosa arkansasensis (Lea) (Pyron and Vaughn, 1994). P. occidentalis, the Ouachita kidney shell, is a C2 candidate for federal listing.

METHODS

Our quantitative survey efforts were restricted to areas that contained concentrations of mussels and thus could be defined as "beds". Mussel relative abundance and habitat data for 22 sites in the Kiamichi River were collected during July - August 1990. These sites included 11 areas defined as "pools", 6 areas defined as "backwaters", and 5 areas defined as "runs" (see discussion). Mussel surveys (timed to standardize sampling effort) (Kovalak et al., 1986; Green et al., 1985) were conducted by hand searching with the aid of SCUBA in deeper areas and by hand searches in shallow areas in the following manner: (1) a shoal was identified for surveying; (2) the entire area was searched by at least two people for one hour; (3) all mussels encountered were removed to shore; (4) all mussels were immediately identified; (5) mussels were put back in the water as close to where they were removed as possible.

At each of the 22 sites we measured water depth, water temperature, current velocity, conductivity, dissolved oxygen, and pH. Five measures of water depth and current velocity were taken across the mussel bed and averaged. Current velocity was measured 10 cm above the stream bottom with a Marsh-McBirney model 201 portable flow meter. Conductivity and dissolved oxygen were measured with YSI meters. pH was measured with a Fisher Accumet portable pH meter.

At each site we recorded proximity of the site to entering tributaries, islands, and macrophyte cover. Three replicate substratum samples were collected at each site. These were brought back to the laboratory and allowed to dry. Samples were dry sieved, weighed, and individual proportions of samples assigned to the appropriate substrate size class (in mm) following Hynes (1970, p. 24). Standard sieving techniques do not segregate particles greater than about 2 mm in diameter (i.e. gravel from pebble from cobble). To determine the proportion of fine gravel, coarse gravel, pebble, and cobble in samples we took the proportion of the sample greater than 2 mm in diameter and randomly measured the diameter of 100 particles in that subsample (Dunne and Leopold, 1978).

In 1991 we selected ten of the 22 sites as long-term population monitoring sites for Arkansia wheeleri (Figure 2). The ten sites were chosen to be as evenly distributed as possible along the Kiamichi River above Hugo Reservoir, but still be reasonably accessible and included sites where A. wheeleri had been located by us in 1990 and sites where it had been found historically (Mehlhop and Miller 1989, Clarke 1987) and sites above and below the impoundment on Jackfork Creek. Density and relative abundance data for mussel species at the ten monitoring sites were collected during July - August 1991. Densities were calculated from quadrat samples and relative abundances were estimated from timed searches, as described above. Quadrat sampling was done with quarter meter square PVC pipe quadrats. Fifteen random quadrats were sampled for each site. Quadrats were searched by hand, with the aid of SCUBA in deeper areas, until all mussels had been recovered to a depth of 15 cm. Individual mussels were returned to the mussel bed as in timed searches. All A. wheeleri found were measured using digital calipers (height, width, and length), and individually marked using numbered, laminated plastic fish tags. A. wheeleri were returned to the precise location from which they were captured.

To obtain additional information on Arkansia wheeleri size and age distribution we measured relict shells of A. wheeleri that had been deposited in the Oklahoma Museum of Natural History (OMNH) or that we found on the Kiamichi River between 1990 - 1992. We counted external annuli on the shells we had collected and those in the OMNH (Neves and Moyer, 1988; McMahon, 1991). We used the above data to calculate shell length, width and height vs. number of annuli regression lines. Shell height vs. number of annuli produced the best fit, and the resulting equation was used to predict the number of annuli for live mussels that had been measured in the field. We used Replicated Goodness of Fit tests (G_H) (Sokal and Rohlf, 1981) to compare size distributions of relict shells and live mussels, and to compare predicted age distributions of mussels above and below the impounded tributary.

We used several statistical techniques to explore relationships between Arkansia wheeleri distribution and abundance and measured habitat parameters. For all of these analyses we used the data collected from the 22 sites in 1990. Associations between A. wheeleri and other species of mussels were calculated using Spearman Rank correlations on relative abundance data (Ludwig and Reynolds, 1988). We used discriminant function analysis (SYSTAT, 1992) to predict the presence or absence of A. wheeleri at a site based on the habitat characteristics of that site. We used an independent sample t-test (one-tail) (Sokal and Rohlf, 1981) to compare species richness at sites with and without A. wheeleri.

RESULTS

Arkansia wheeleri were found in 10 of the 22 mussel beds that were sampled. Six of these 10 sites were classified as pools and four were classified as backwaters. A. wheeleri did not occur in any of the run areas sampled. A multivariate analysis of variance using all of the habitat variables to predict the presence or absence of A. wheeleri at a site was not significant ($F_{(12,9)} = 1.22$, $P = 0.39$). A significant discriminant model was produced using four habitat variables: depth, habitat type (pool, backwater, or run), presence or absence of emergent vegetation at the site, and mussel species richness (Table 1). This model successfully predicted the presence or absence of A. wheeleri 17 out of 22 times ($G_{(1)} = 7.72$, $P = 0.005$). Mussel species richness at a site was the best individual predictor of A. wheeleri occurrence (Table 1). Mussel sites where A. wheeleri occurred were more species-rich than other mussel sites that we sampled in the Kiamichi River (Figure 5, $t_{(15)} = 3.18$, P=0.006).

Spearman rank correlations of relative abundance data revealed three significant associations between Arkansia wheeleri and other mussel species. A. wheeleri was positively correlated with the relative abundance of Quadrula c.f.appiculata (r_s=0.437, P < .05) and Megalonaias nervosa (r_s = 0.423, P < .05), and negatively correlated with Lampsilis teres (r_s = -0.368, P < .05).

In most cases Arkansia wheeleri were located only through timed searches and did not occur in quadrat samples. Mean relative abundance of A. wheeleri at monitoring sites in 1990-92 is shown in Figure 3 and varied from 0.2% to 0.7%. In 1991, A. wheeleri was found in quadrat samples at two sites, 6 and 7. This allowed us to calculate the density of A. wheeleri at these two sites. The density of A. wheeleri was 0.27 individuals per square meter at both of these sites.

In both 1990 and 1991 we marked and released at the point of capture nine Arkansia wheeleri. In 1991 we recaptured only two marked individuals, although we found nine live individuals. Both recaptured A. wheeleri were found at site 3 (Figure 2). Both of these individuals were found within one meter of where they were released in 1990. No other live A. wheeleri were found at site 3. In 1992 we recaptured the same two A. wheeleri at site 3 that we had recaptured in 1991. The individuals were within a few meters of where they had been released in 1991. The recaptured individuals had not grown discernably (i.e. more than 1 mm, within the margin of error of our calipers). No other marked A. wheeleri were recaptured in 1992. The size distribution (means for 1990 - 92) for A. wheeleri in the Kiamichi River is shown in Figure 4.

The overall size distribution of relict shells in the OMNH (n = 50) was significantly different than the size distribution of live Arkansia wheeleri in the Kiamichi River (n = 43) (Figure 4, $G_{H(5)} = 23.1$, $P < .001$). The resulting regression equation for number of annuli on shell height was $Y = (-.483)X + 49.62$ ($n=24$, $R^2=0.467$, $P < 0.05$). Predicted ages based on number of annuli for live A. wheeleri from the Kiamichi River are shown in Figure 5. Predicted age distributions of spent shells vs. live A. wheeleri were also significantly different ($G_{H(12)} = 57.43$, $P < .001$). Using this technique, the youngest predicted age for a live A. wheeleri was 12 years. If this estimate is accurate, none of the A. wheeleri we encountered on the Kiamichi River during our study were produced after Sardis Reservoir was filled in 1983.

Arkansia wheeleri occurs both above and below the inflow to the Kiamichi River from Sardis Reservoir via Jackfork Creek. Of our ten monitoring sites, three were located above Sardis Reservoir and seven below (Figure 2). All of these sites historically harbored A. wheeleri. A. wheeleri was found during this study at all three sites (100%) above Sardis Reservoir. A. wheeleri was found at three of seven (43%) of the sites below the reservoir inflow. The relative abundance of A. wheeleri at sites above Sardis reservoir was on average greater than the relative abundance of A. wheeleri at sites below the reservoir (Figure 3), although these differences were not statistically significant.

DISCUSSION

Prior to this study, the habitat of Arkansia wheeleri was reported to be backwater reaches of rivers where current is slow and where there are relatively non-shifting deposits of silt/mud and sand (Wheeler, 1918; Isely, 1924; Clarke, 1987). We found that A. wheeleri occurs in both pools and backwaters in the Kiamichi River, not just backwaters as was previously believed. The distribution of A. wheeleri may have been underestimated in past surveys because backwaters are relatively easy to survey, whereas pools often require SCUBA techniques.

Although pools and backwaters were considered different habitat types in this study, in reality they are tightly interconnected and share many characteristics in common. Backwater areas tend to be shallower and have finer substrata. As backwaters merge into the main river channel they turn into deeper pools with coarser substrata and slightly higher current velocities. In the Kiamichi River Arkansia wheeleri occurs in both of these habitats. In addition we believe A. wheeleri moves back and forth between these habitats either voluntarily or through physical displacement of shifting sediments. Locomotory tendencies differ among different mussel species. For example, Anodonta grandis (Say) migrate up and down with changes in water level (White, 1979) and in this way avoid stranding at low water. Other species such as Uniomerus tetralasmus (Say) and the introduced Corbicula fluminea (Muller) remain in position and suffer prolonged exposure to air (McMahon, 1991). Marked individual A. wheeleri in a backwater area (site 3) did not move significantly from July 1990 to July 1992. However, at another site (site 5) unmarked individuals moved from a backwater area into the adjacent pool area. This movement was probably the result of physical displacement of these individuals through sediment scour and redeposition.

Unlike previous surveys (Wheeler, 1918; Isely, 1924; Clarke, 1987), we did not find Arkansia wheeleri to be restricted to areas where the substratum was predominantly mud or fine sand. In the Kiamichi River A. wheeleri is just as prevalent in gravel/cobble/coarse sand substrata (which predominates in pools) as in finer substrata. Recent studies addressing the substratum preferences of unionids have reached different conclusions, and substratum preferences among unionids remain poorly understood. However, mussels are generally believed to be most successful in stable, sand-gravel mixtures and are generally absent from substrata with heavy silt loads (Cooper 1984, Salmon and Green 1983, Stern 1983, Way et al. 1990). Most unionid species can be found on a number of different substrata, but growth rates of individuals in each microhabitat can be quite different (Kat 1982, Hinch et al. 1989). Furthermore, many mussel species can occupy a wide range of habitats as a result of extensive larval dispersal over a heterogenous stream environment (Strayer 1981), but growth and reproduction may be optimized only under the habitat conditions described above.

Arkansia wheeleri only occurred at the most species-rich sites in the Kiamichi River. These shoals represent optimal habitat for most mussel species, as evidenced by the large number of species and their high abundance. These shoals usually contain both pool and backwater areas, have significant gravel bar development with accompanying vegetation (dominated by Justicia americana), and are close to a tributary (usually within one quarter mile). Shoals are usually adjacent to a major riffle area, although they can be either up or downstream of the riffle. Other studies have shown that these mainstream river shoals in shallower areas with slow, steady current and vegetation and coarse substrate are optimal habitat for lotic unionids because of minimal turbulence, low silt and steady food supply (Salmon and Green, 1982).

In the majority of mussel species the greatest amount of growth occurs in the first few years of life. Shell growth rate then declines exponentially with age, although the rate of tissue biomass accumulation usually remains constant (McMahon, 1991). Our examination of live Arkansia wheeleri in the Kiamichi River and of relict A. wheeleri shells in the museum collections indicate that this growth pattern is also followed by A. wheeleri. Early annuli (those near the umbo) are much wider than later annuli near the edge of the shell.

Recruitment, growth and survival of mussels is often assessed by monitoring changes in density and size demography of natural populations (Payne and Miller, 1989). We have no quantitative historical data on densities of Arkansia wheeleri in the Kiamichi River or anywhere else. Past size distribution, however, can be assessed by examining the size distribution of relict shells. The size distribution of live A. wheeleri in the Kiamichi River is skewed to the left (Sokal and Rohlf, 1981) (Figure 4) with more large individuals and fewer small individuals than one would expect from a statistically normal distribution. The size distribution of relict shells (Figure 4) follows a more normal distribution, with a greater proportion of smaller individuals than in the live population. Looking at these shell length data alone one would conclude that the size distribution of A. wheeleri in the Kiamichi River has changed over time and recruitment has decreased.

External annular rings have long been used to determine mussel age and growth rates. Recently this technique has been criticized as being replete with problems (Neves and Moyer, 1988; Downing et al., 1992). Natural erosion and corrosion of shells makes it difficult to distinguish true from false annuli. For example, false annuli can be formed by the incorporation of small substrate particles into mussel shells. It is difficult to count closely deposited growth lines near the margins of old shells. This produces an underestimate of shell age that becomes more erroneous with shell age. Downing et al. (1992) studied populations of Lampsilis radiata (Gmelin) and Anondonta grandis (Say) in an oligotrophic lake. In these populations, many mussels showed no new external annuli at all, even several years after individual animals had been marked. They concluded that estimates of growth based on shell annuli consistently overestimated real shell growth. In addition, shell size and growth rates are linked to environmental conditions. For example, some species form narrower shells in coarser substrates (Hinch et al., 1989) or grow faster in sand than in mud (Hinch et al., 1986). However, taking into account the large margin of error in using this method, most Arkansia wheeleri encountered in the Kiamichi River are old. Using this method, the youngest live A. wheeleri we encountered was approximately 12 years in age. No juveniles were encountered. Both types of data, shell-size distributions and ages predicted from external annuli, demonstrated that most A.

wheeleri encountered in the Kiamichi River are old.

Because of its rarity, the reproductive biology of Arkansia wheeleri remains unknown. Like other anodontines, it is probably bradytictic. The closest relative of A. wheeleri, Arcidens confragosus (Say), becomes gravid in the fall and releases glochidia in the spring (Clarke, 1981). We were unable to obtain any gravid A. wheeleri and thus obtained no glochidia. A. wheeleri glochidia are probably similar to other alasmidontine glochidia. Alasmidontine glochidia are asymmetrical and have a stylet covered with microstylets which facilitate attachment to the fish host. Glochidial releases are probably tied to natural water temperature changes in the spring and fall (Jirka and Neves, 1992).

It appears that historically Arkansia wheeleri did equally well above and below the impounded tributary to the Kiamichi River (Clarke, 1987). Historically, A. wheeleri occurred in at least seven sites below the tributary. However, in five years of combined sampling effort by Mehlhop and Miller (1989), 1988-1989, and ourselves, 1990-1992, only three subpopulations of A. wheeleri have been found below Jackfork Creek. Therefore, only three out of seven or 43% of the known subpopulations of A. wheeleri survive below Jackfork Creek. In contrast, three out of four or 75% of the historical locations of A. wheeleri above Jackfork Creek have been confirmed and five new locations have been discovered. No new locations have been discovered below Jackfork Creek despite intensive survey efforts. In addition, the relative abundance of A. wheeleri is slightly higher above Jackfork Creek than below. Unfortunately, we have no historical abundance data for A. wheeleri in the Kiamichi

River.

The greatest threats to the continued existence of Arkansia wheeleri in the Kiamichi River are land use changes, including further impoundment of the river, water transfers, timber harvesting, and pollution from agricultural and industrial development (Neves 1993, Mehlhop and Vaughn 1994). A. wheeleri is also threatened by the invasion of exotic bivalve species, particularly the zebra mussel, Dreissena polymopha. D. polymorpha are now found in the Arkansas River system in Oklahoma. The high dispersal capabilities of this species make it highly probable that it will invade the Red River system, including the Kiamichi River, in the near future (French 1990).

ACKNOWLEDGEMENTS

We thank John Alderman, Tambra Browning, David Certain, Julian Hilliard, David Martinez, Estelle Miller, David Partridge, and Matthew Winston for help with field work at various times. Matthew Craig performed the annuli counts on Arkansia wheeleri and Christopher Taylor commented on the manuscript. This study was funded by the U.S. Fish and Wildlife Service and the Oklahoma Department of Wildlife Conservation through Endangered Species Act funding (project E-12).

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Table 1. Results of univariate F-tests of the presence or absence of Arkansia wheeleri at a site using four habitat variables. The multivariate model is significant ($F_{(1,20)}$ = 0.54, P = 0.03).

Variable	$F_{(4,17)}$	P
Depth	6.87	0.016
Habitat type (pool, backwater, or run)	0.95	0.342
Emergent vegetation (presence/absence)	5.45	0.030
Mussel species richness	10.72	0.004

FIGURE CAPTIONS

Figure 1. Rivers in which Arkansia wheeleri historically occurred.

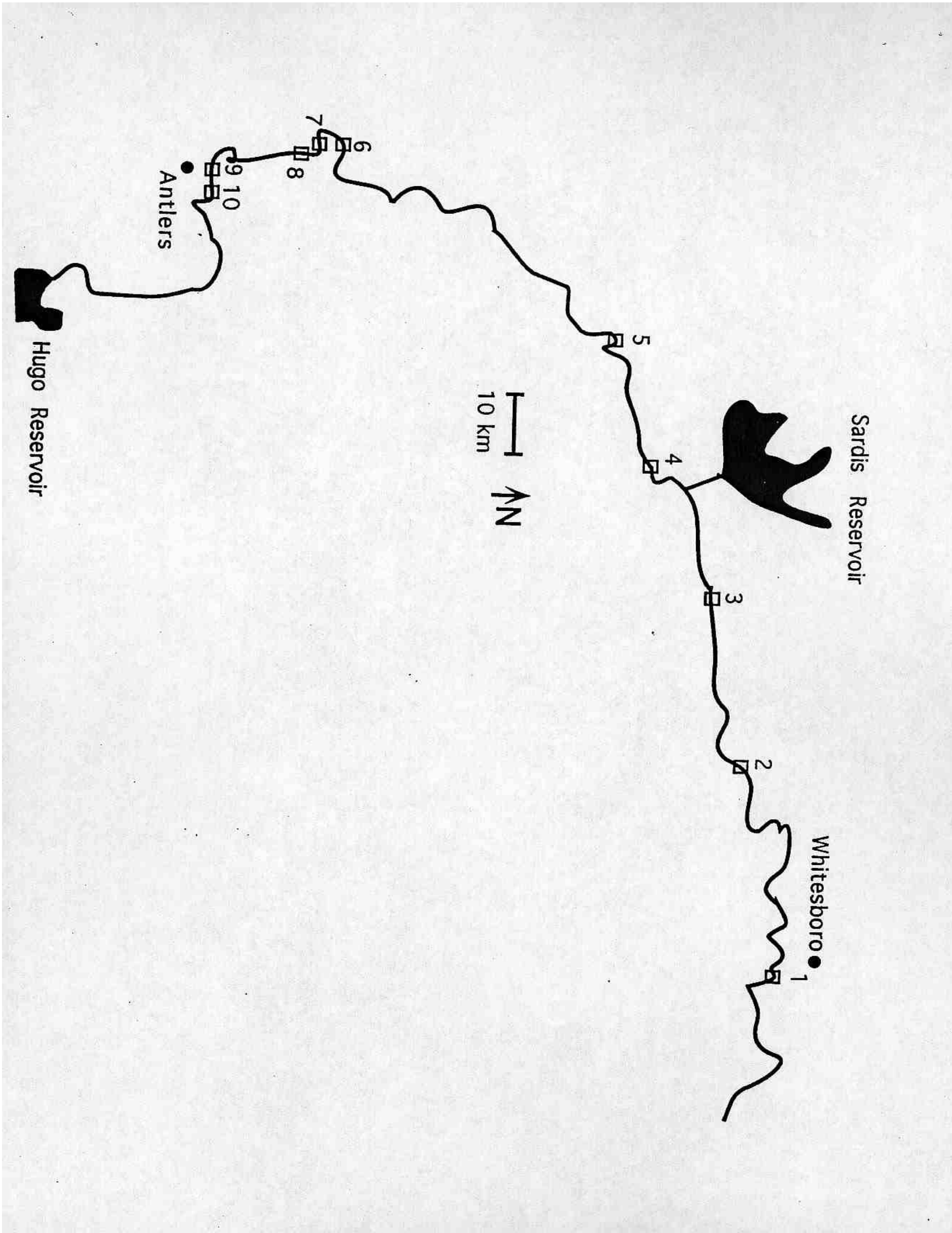
Figure 2. Population monitoring sites for Arkansia wheeleri on the Kiamichi River.

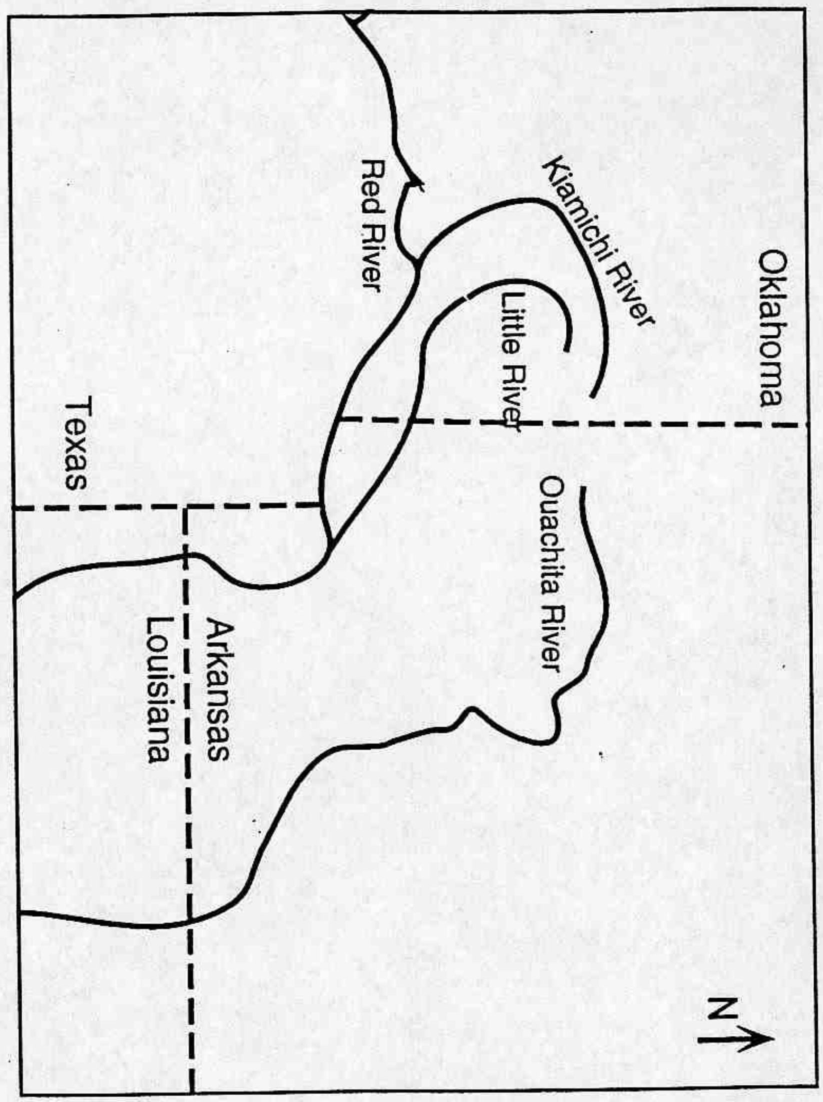
Figure 3. Mean relative abundance of Arkansia wheeleri at the 10 monitoring sites in 1990 - 1992.

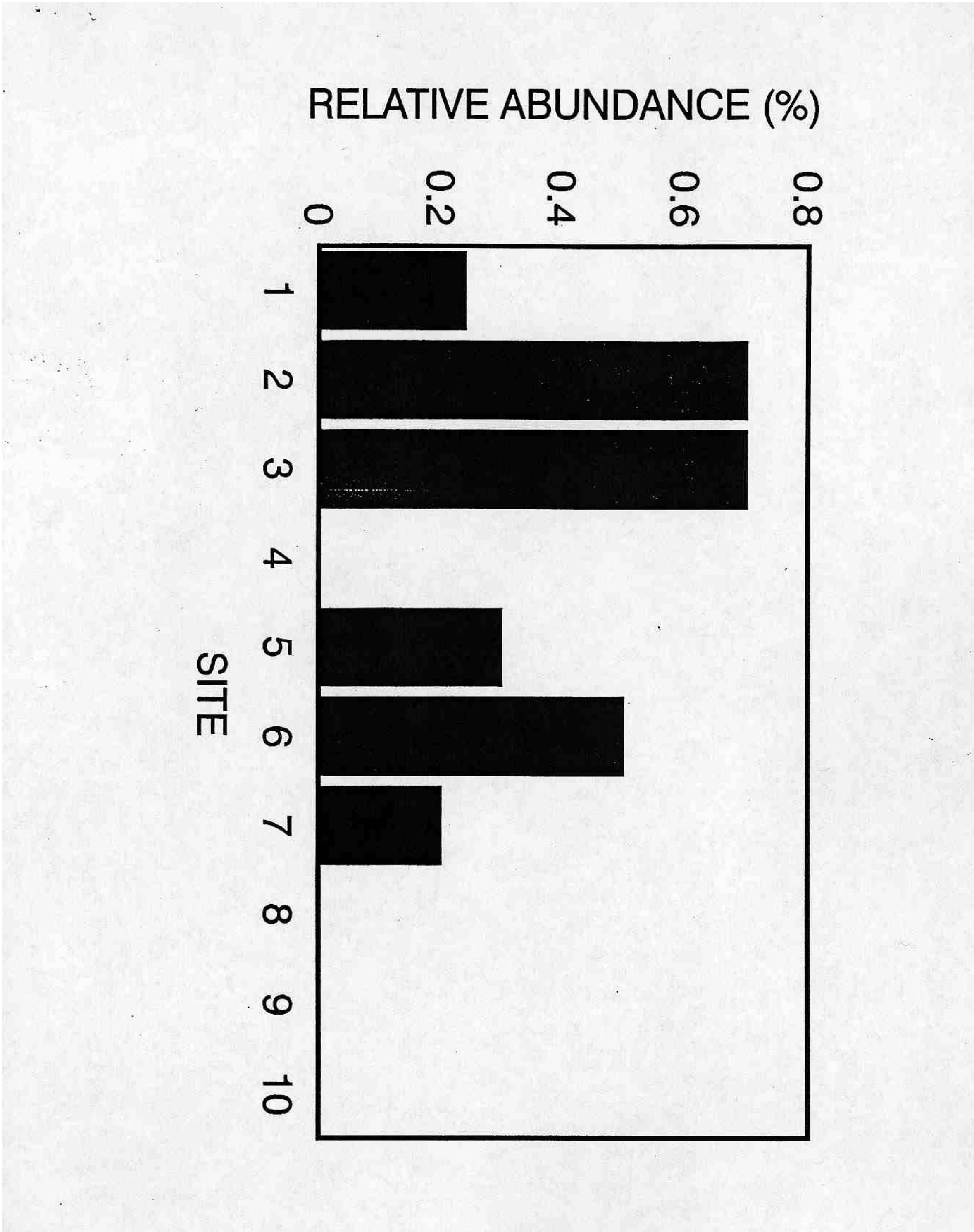
Figure 4. Total lengths of live Arkansia wheeleri compared to relict shells from the Kiamichi River.

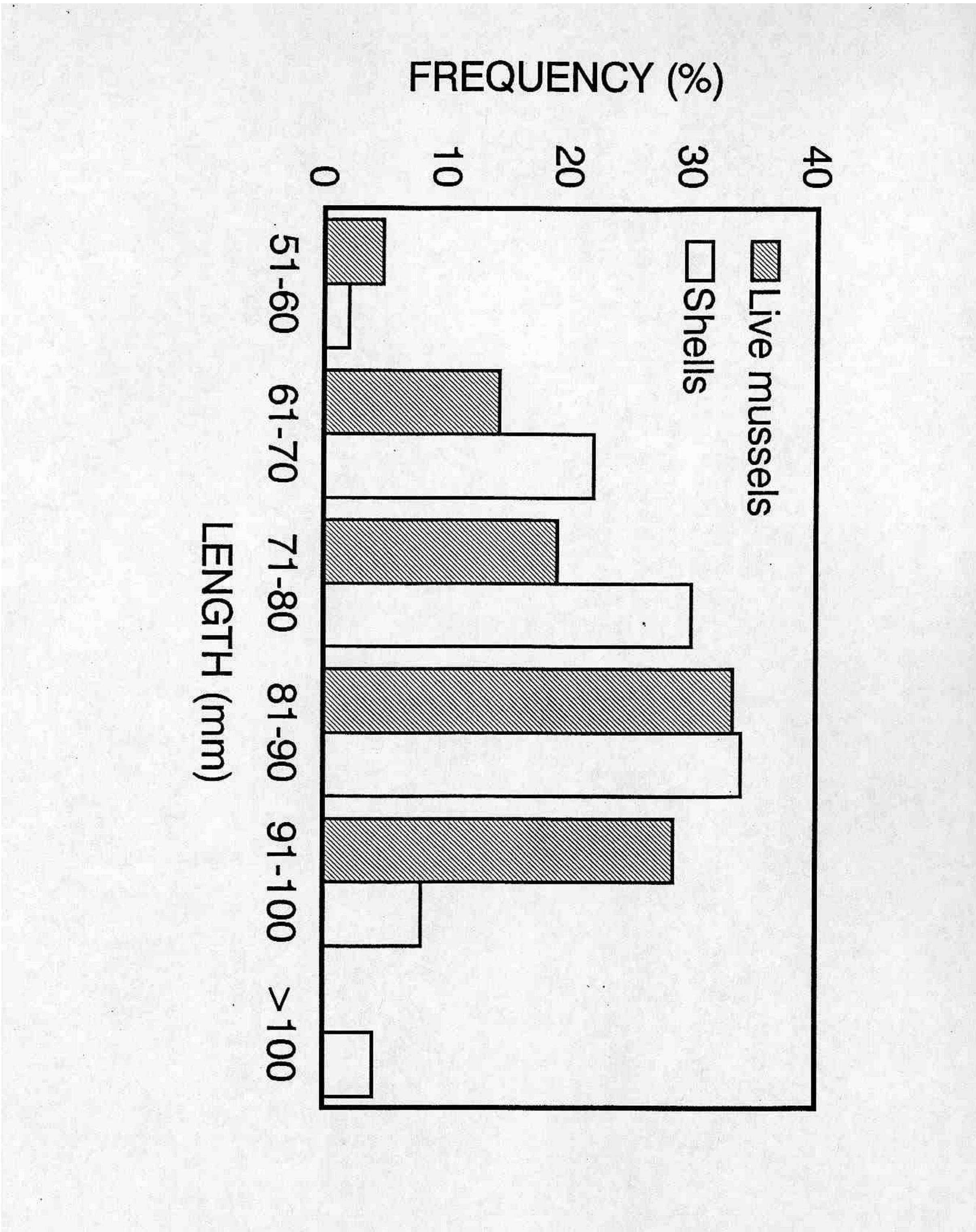
Figure 5. Predicted number of annuli for live Arkansia wheeleri versus relict shells from the Kiamichi River.

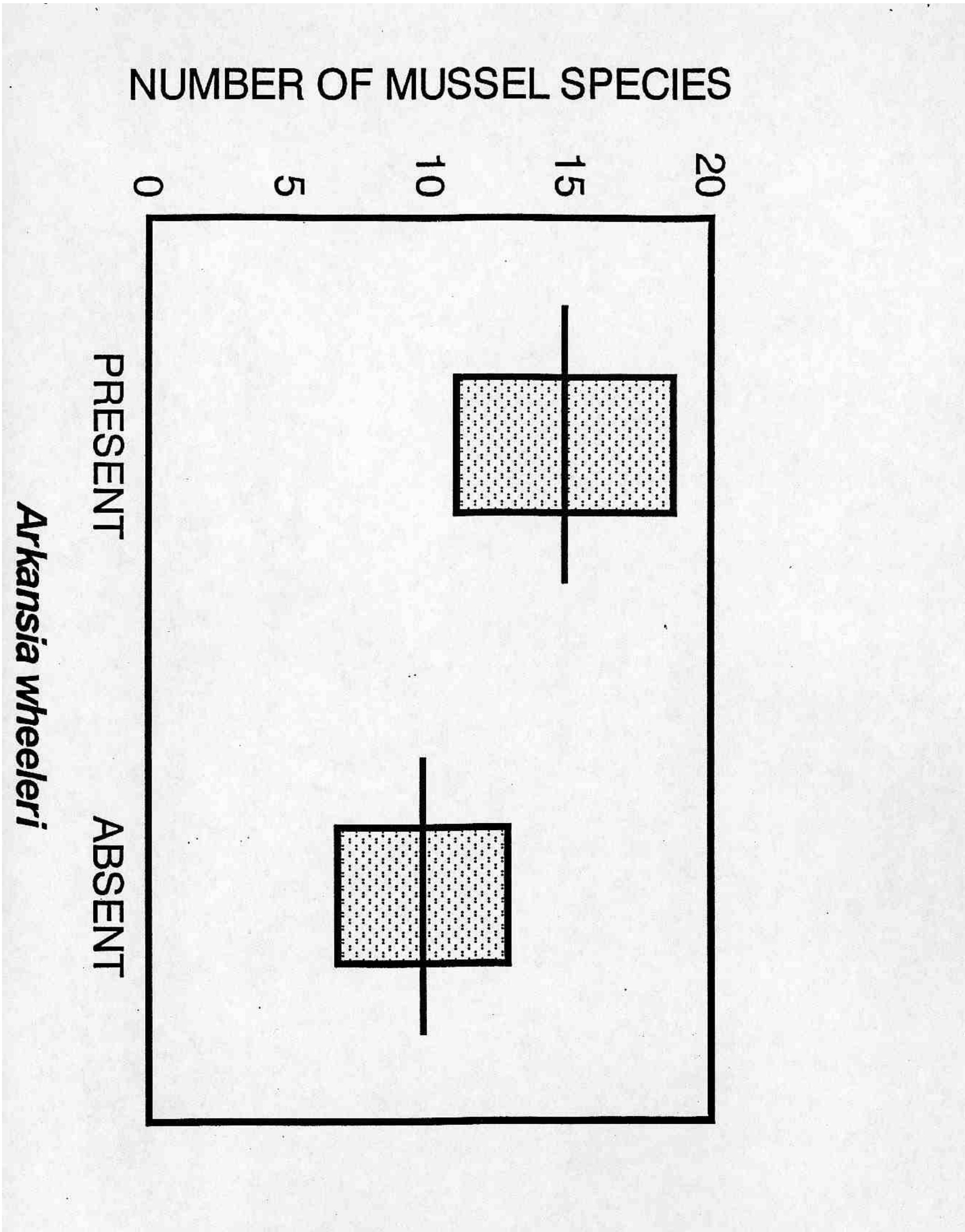
Figure 6. Mussel species richness (mean and standard deviation) at sites with and without Arkansia wheeleri. Data are from the 22 sites sampled in 1990.

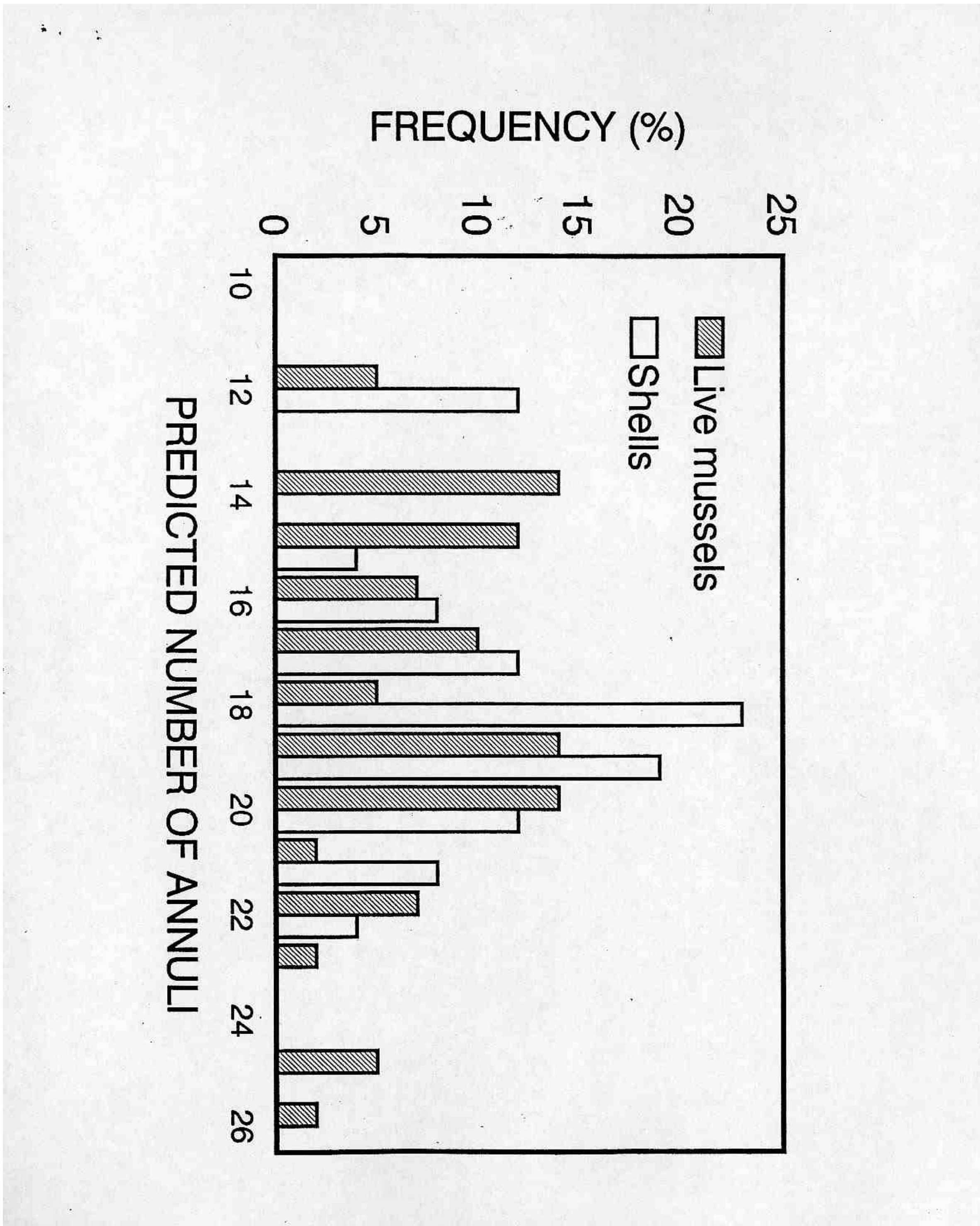

Sardis Reservoir
Whitesboro
1
2
3
4
5
6
7
8
9
10
10 km
N
Antlers
Hugo Reservoir


Oklahoma
Kiamichi River
Little River
Red River
Texas
Ouachita River
Arkansas
Louisiana
N


RELATIVE ABUNDANCE (%)
0
0.2
0.4
0.6
0.8
1
2
3
4
5
6
7
8
9
10
SITE


FREQUENCY (%)
0
10
20
30
40
Live mussels
Shells
51-60
61-70
71-80
81-90
91-100
>100
LENGTH (mm)


NUMBER OF MUSSEL SPECIES
0
5
10
15
20
PRESENT
ABSENT
Arkansia wheeleri


FREQUENCY (%)
0
5
10
15
20
25
Live mussels
Shells
10
12
14
16
18
20
22
24
26
PREDICTED NUMBER OF ANNULI

Threats to and Sustainability of Ecosystems for Freshwater Mollusks

Patricia Mehlhop[1] and Caryn C. Vaughn[2]

Abstract — In North America, two groups of freshwater molluscs are most threatened by human activities and require ecosystem approaches to their sustainability. Prosobranch snails in the family Hydrobiidae are restricted to small spring systems and are limited by their relative immobility, dependence on highly oxygenated waters and use of gills. Many are narrow endemics of localized springs, which are altered by ground water depletion and surface water diversion and by changes in water quality such as nutrification and chemical pollution from non-point sources. Spring alteration can result in direct species extirpation. Conservation through threat assessment and abatement is recommended. Most rare and declining native mussels are Unionidae in riverine ecosystems. Their relative immobility, long lifespan, filter-feeding habits, and parasitic larval stage make them highly vulnerable to habitat disturbance. The major cause of their declines has been the fragmentation of river ecosystems through impoundments, channelization and other activities such as timber harvesting, which alter flow and sedimentation patterns. Fragmentation acts to increase the distance between mussel subpopulations and may have major consequences of the metapopulation structure of species, particularly rare species and those with narrow fish host requirements. As some populations are eliminated and dispersal distances are increased, demographic and genetic constraints will diminish the ability of local populations to respond to natural environmental disturbance as well as human-induced changes. Sustainable ecosystem management in river systems will require devising strategies to conserve mussel metapopulations.

INTRODUCTION

Lotic systems harbor a diverse array of species, including some of the most threatened (Allan and Flecker 1993). Those in the United States have been altered by humans in ways that often are detrimental to their native inhabitants. One consequence of this is that the native molluscan fauna in those systems has declined. We examine here ecological and life history characteristics of two groups of molluscs, prosobranch snails in the family Hydrobiidae and riverine bivalves in the family Unionidae, that have suffered declines due to human activities or appear to be threatened with declines in the future. Their distribution and life history characteristics render them vulnerable to human alteration of their habitats.

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HYDROBIIDAE

The aquatic snail family Hydrobiidae is species rich and ranges worldwide. Many of the North American species occur as narrow endemics in one or a few small spring systems as living "fossils" that flourished during the Pleistocene (Deixis 1992, Taylor 1987). The systematic relationships of most North American species have only recently been addressed (Hershler 1984, 1985, 1989; Hershler and Landye 1988; Hershler and Longley 1986; Hershler and Sada 1987; Hershler and Thompson 1987; Taylor 1987; Thompson 1968, 1969), and many species remain undiscovered and undescribed (T. Frest, personal communication, R. Hershler, personal communication). Currently, 5 species have been listed as endangered (Federal Register 1991a, 1992), 10 are considered to merit listing as endangered or threatened, and 84 are under review for listing (Federal Register 1991b) (fig. 1).

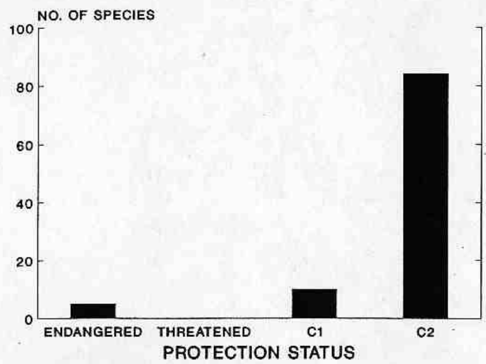

Figure 1.—Federal status toward listing of rare or declining snails of the family Hydrobiidae in the United States. Histogram shows number of species listed as endangered or threatened, number of candidate 1 species (species that merit listing) and number of candidate 2 species (species requiring further study to determine status).

Freshwater hydrobiids are indicators of artesian spring ecosystems with permanent, flowing, highly oxygenated waters (Ponder et al 1989). The waters may be highly mineralized, but must be relatively unpolluted. When hydrobiids occupy a significant portion of a spring system, it is an indication that the system is functioning and intact.

Life History and Ecological Characteristics

Hydrobiids are gill breathing and thus intolerant of drying or anaerobic conditions. Reproduction occurs annually or more often depending on water temperature (Deixis 1992, Hershler 1984, Mladenka 1992, Taylor 1987), and survivorship is estimated to be approximately one year (Mladenka 1992, T. Frest personal communication). They are found in flowing waters, often in thermal springs. The ecology of these snails in North America has received little study until recently (eg., Deixis 1992, Hershler 1984, Mladenka 1992, Reiter 1992). Here we examine ecological data for 59 species in the subfamilies Hydrobiinae and Littoridininae that have been reported as rare or threatened, or which occur in a narrow range in springs and their associated outflows. The sources of information consulted for each species are given in Appendix 1.

Of 59 species, most occur at only a single site and most of the remaining occur at only two or three sites (fig. 2). Occurrences represent single springs with no surface connection to other inhabited springs or parts of spring systems separated by more than 500 m of uninhabited waters. Because studies have not been conducted on gene flow among occurrences, it is not known whether an occurrence is the equivalent of a population.

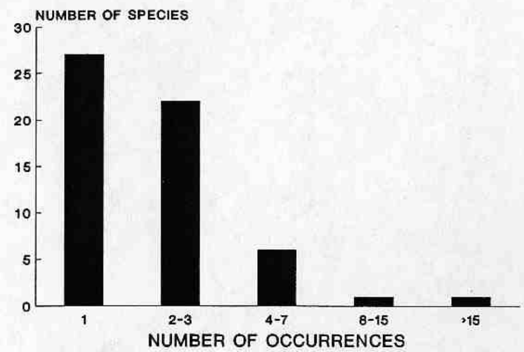

Figure 2.—Number of known occurrences per species of hydrobiid snails that are rare or threatened or have a narrow range of distribution.

Maximum occupied range was estimated in miles for 58 species as the greatest linear distance between two occupied points. Of those, 43% are known to occupy a range less than 0.1 mile, and less than 9% have a range greater than 10 linear miles (fig. 3).

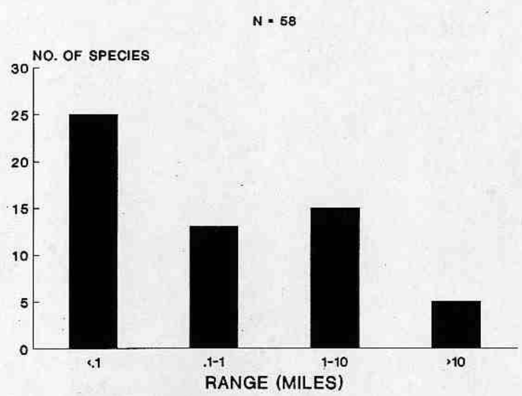

Figure 3.—Maximum occupied range per species (linear miles) of hydrobiids in the subfamilies Hydrobiinae and Littoridininae that are rare, threatened or have a narrow range of distribution.

Substrates occupied by each of 50 species were grouped into seven substrate types. Species in the Littoridininae were most often reported on vegetation, including algal mats and on soft substrates, such as mud and flocculent, but they were reported also on fine substrates such as silt and sand and on tufa (fig. 4). Species in the Hydrobiinae were reported from the same substrates as Littoridininae and also from wood, from stones, including pebbles and cobble, and from boulders and bedrock. It is not clear whether substrate associations reflect particular substrate preferences or hydrologic regimes of the occupied springs and spring runs, which in turn influence substrate availability. Mladenka (1992) showed experimentally that *Pyrgulopsis bruneauensis* (subfamily Hydrobiinae) preferred gravel and sand to silt.

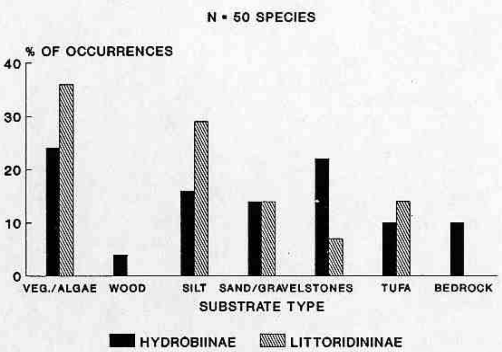

Figure 4.—Reported substrates at occurrences of hydrobiid snails in the subfamilies Hydrobiinae (N = 60 occurrences) and Littoridininae (N = 27 occurrences).

The extreme endemism of the species surveyed, as measured by the number of occurrences and occupied range, suggests that they may be extremely vulnerable to human disturbance. Threats to viability were assessed or identified for 53 species (fig. 5). When more than one threat was identified for a species, the two most prominent threats were tabulated. Decrease in water quantity, due to aquifer depletion or surface water diversion, was identified as a threat for 33 species, with many of those species threatened by both aquifer depletion and surface water diversion. Declines in water quality, due to habitat destruction (from impoundment, dredging or cattle trampling), or pollution (nutrient or chemical), was identified as a threat for 21 species. Recreation, such as swimming or hot spring bathing, was identified as a threat for 10 species. A study by Reiter (1992) suggests that recreation may not be as severe a threat as a change in water quantity or quality. He found that swimmers at a spring in Florida displaced *Aphaostracon monas* from a small area favored by both swimmers and snails, but the snails repopulated the area following the swimming season. For 2 species, no threats were identified in threat assessment procedures.

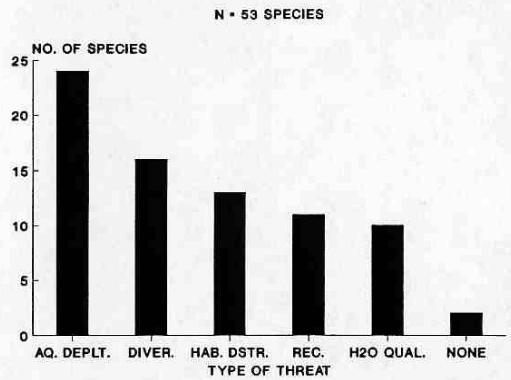

Figure 5.—Reported threats to snails in the family Hydrobiidae. AQ DEPLT = aquifer depletion, DIVER = water diversion, HAB DSTR = habitat destruction, REC = recreation, H2O QUAL = water quality, NONE = no threats found.

Ecosystem Sustainability

Species on public land and on private land designated for conservation offer some degree of long-term protection of ecosystems (Crumpacker et al. 1988). The number of occurrences for 59 hydrobiids was tallied by land ownership (fig. 6), multiple owners of any single occurrence were each counted as an owner. The greatest number of occurrences were on federal lands managed by the Bureau of Land Management (BLM) with private owners having the second greatest number. However, most of the occurrences on BLM lands were attributed to over 100 occurrences of *Pyrgulopsis bruneauensis* in springs along less than 10 miles of a water course (Mladenka 1992), a concentration of occurrences that has not been reported for other North American hydrobiids. If these are clustered as a single occurrence, 85 of the reported occurrences, or 65%, are on public lands or private conservation lands, 44 (33%) are on private lands other than those with a conservation interest and 3 (2%) are on tribal lands. Springs in western states are frequently in private ownership, often as inholdings or adjacent to large tracts of public land, while in Florida many are in the State Park system (Florida Natural Areas Inventory 1992).

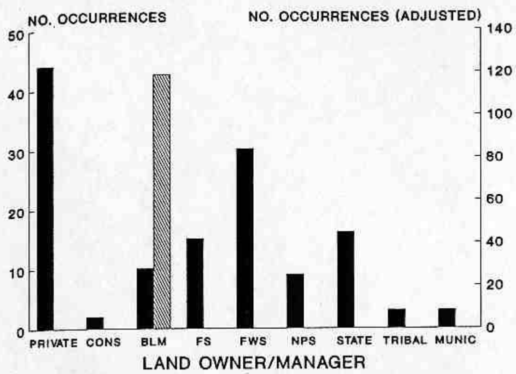

Figure 6.—Land owner or management agency of sites where hydrobiid snails in this study occur. When more than one owner was reported for a species occurrence, each owner was counted. The hatched bar shows the number of occurrences on BLM land without adjustment for the close clustering of over 100 occurrences of a single species. PRIVATE = private land with no formal protection status, CONS = private land with protection status, BLM = Bureau of Land Management; FS = USDA Forest Service, FWS = Fish & Wildlife Service, NPS = National Park Service, MUNIC = municipal ownership or control.

Recommendations for Ecosystem Sustainability

Most freshwater hydrobiids that have been reported as rare or threatened, or which occupy a narrow range, occur in one or a few artesian springs and their associated outflows (figs. 2 and 3). The aquifer source and hydrology of most of the spring systems is not well understood and because of this, hydrobiid ecosystems tend to be defined in reference to the surface waters of the host springs and outflows. When several springs are in close proximity to one another and have one or more hydrobiid species in common, they tend to be treated as a single system for management purposes (Deixis 1992; Federal Register 1991, 1992; Mladenka 1992). Hydrobiid-occupied springs are spatially small ecosystems, which is an advantage for management toward sustainability.

However, conservation and management planning needs to begin at a level higher than single spring ecosystems. For instance, a few spring systems, such as the Ash Meadows system in Nevada (Hershler and Sada 1987) and the Cuatro Cienegas system in Coahuila, Mexico (Hershler 1984, 1985) are quite large with several endemic species in various subsets of springs within the large system. In such cases, management needs to begin with the entire spring system. Artesian springs, especially those in arid environments, are analogous to islands in a sea of dry land that is inhospitable to aquatic species (Ponder et al. 1989). Striking regional species radiations have been demonstrated for both fishes (Soltz and Naiman 1978) and hydrobiids (Ponder et al. 1989, Thompson 1968). This argues for management perspectives that are at regional or large ecosystem levels rather than at the level of single isolated springs.

In many instances, springs are components of larger riverine ecosystems, though hydrologically distinct from them. Two examples of this are the Gila River ecosystem in southwestern New Mexico, which is a riverine ecosystem with eight known spring ecosystems occupied by hydrobiids (Mehlhop 1992 and unpublished data, Taylor 1987), and the middle Snake River with numerous associated springs (Deixis 1992, Federal Register 1992). In those situations, spring management must be a special target of management plans for larger ecosystems.

Most spring ecosystems examined in this survey are best sustained through threat analysis and control. Systems that are highly degraded with marginal hydrobiid populations probably cannot be restored without large financial expenditure and may not be worthy of investment if other, more naturally functioning spring ecosystems can be protected. Systems such as Torreon Spring in New Mexico, which has been impounded to an extent that the hydrobiid *Pyrgulopsis neomexicana* occupies less than 1 m^2 of its former range, is an example of an ecosystem that is no longer functional in its natural state (personal observation). The following recommendations for sustaining spring ecosystems for hydrobiids use a threat assessment and control approach.

1) Identify all springs in the landscape with hydrobiid snails and prioritize them for conservation.
2) Monitor and maintain water quantity in priority spring ecosystems.
3) Monitor and maintain water quality in priority spring ecosystems.
4) Identify and assess the need to abate other threats to ecosystem sustainability.
5) Quantitatively monitor occupied hydrobiid habitats within the targeted springs. In spring ecosystems with co-occurring hydrobiids, monitor relative numbers.

Monitoring will be the most time consuming action in sustaining many spring ecosystems. In most instances, it need not be elaborate, but it must be repeatable and occur at a frequency that will indicate decline in the parameters being monitored.

Hydrobiids are minute and easily overlooked by an untrained observer. To avoid investing in spring ecosystem management in lower priority spring systems, it is important to survey all springs and seeps in a large landscape (e.g., a National Forest and adjacent lands with similar landscape features). Primary threats to hydrobiid-occupied springs should then be identified and management actions prioritized based on assessments of species rarity, population size, degree of threat and amenability of threats to control measures.

Surface water diversion is readily detected and easily monitored. However, protection of surface waters alone is insufficient for many of the spring ecosystems. There are a large number of species for which ground water depletion has been identified as a major threat (fig. 5). Monitoring and protection of ground water flows for those systems is probably the single most important management need. This requires assessing the uses and regulation of the spring aquifer, for which depth and size are most often unknown. A long term monitoring program that roughly estimates water quantity at a spring may be an inexpensive, but adequate means of detecting ground water depletion.

For spring ecosystems that are a high priority for conservation, water quality should be measured initially to obtain baseline water quality data. The subsequent frequency of monitoring will vary with degree of threat. Results of this survey suggest that recreation is a threat to spring ecosystems only if spring outflows are altered substantially or if chemicals are added to the system. For instance, a hot spring in New Mexico is used for recreational bathing upstream from one of only two populations of a hydrobiid, and the population is maintained by flows of 0.3 cm and less over the snail substrate. While the probability of diversion or chemical pollution appears low, the consequences of such threats could be great.

Monitoring the snails themselves provides both a measure of the impacts of identified threats and a means of detecting unanticipated threats. Hydrobiid snail populations are difficult and costly to estimate, and methods used at one spring system may not be applicable to others (personal observation, T. Frest, personal communication). However, population stability can be estimated by monitoring the surface area occupied or the boundary of occupation. This needs to be done at approximately the same time of year due to seasonal population fluctuations generally associated with birth and death events. When hydrobiids co-occur in a spring, they usually cannot be distinguished with certainty without some disturbance to the population. However, some minimal monitoring is desirable to confirm that species proportions remain relatively stable.

UNIONIDAE

The unionid mussel fauna of North American freshwater is the most diverse in the world but is highly threatened. There have been major declines of mussel populations and species diversity in North American over the last century. Of the 283 species of native North American mussels, 131 species, or approximately 40%, are threatened with extinction: 17 species are presumed extinct, 44 species are actually listed as threatened or endangered, and 70 species are federal candidates for listing (Neves 1993, Master 1993) (fig. 7). Furthermore, all federally listed unionids are declining. There are no listed species with populations that are being maintained or increasing (Neves 1993).

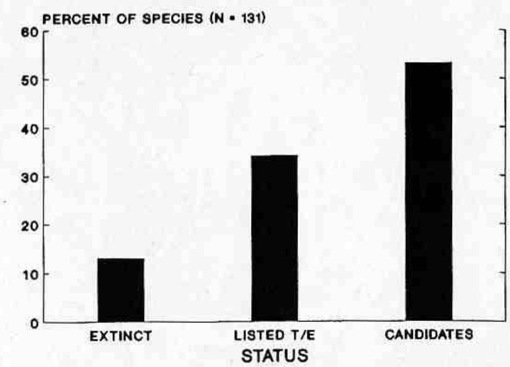

Figure 7.—Status of unionid mussels in the United States. N = 131. LISTED T/E = listed by the federal government as threatened or endangered, CANDIDATES = candidates for federal listing.

Unionid Characteristics

Freshwater mussels possess a suite of traits that make them highly vulnerable to habitat disturbance (table 1). Mussels have a complicated life history. The larval stage of freshwater mussels (glochidia) are temporary, obligate parasites on the gills or fins of fish. Many mussel glochidia can survive only on a narrow range of fish species hosts (Way 1988). Contact with an appropriate fish host and the location where young mussels are shed from the host is largely due to chance and only juveniles that reach a favorable habitat survive (Neves & Widlak 1987). Because only larvae can move between patches and juvenile survival is low, the potential rates of colonization are low. Reproductive maturity is not reached until age 6, most species live greater than 10 years, and some species live as long as 90 years (Haskin 1954, Imlay 1982, McMahon 1991). Once mature, adult mussels exhibit high survivorship (>80%) (McMahon 1991). However, adult mussels are sedentary; movements are

Table 1. — Life history characteristics of the Unionidae. Modified from McMahon (1991).

Life span	< 6 > - 100 yr
Age at maturity	6 - 12 yr
Strategy	Iteroparous
Fecundity	200,000-17,000,000
Reprod. efforts/year	1
Juvenile size	50 - 400 um
Rel. juvenile survivorship	Very low
Rel. adult survivorship	High
Larval habitat	Obligate parasite on fish

seasonal and on a scale of a few to an estimated maximum of 100 meters (Green et al. 1985). Therefore, unlike many stream organisms such as fish and aquatic insects (Townsend 1989), adult mussels have no refugia from disturbance events in streams. In addition, their filter-feeding habits make them especially vulnerable to sedimentation and chemical pollution events.

Threats and Causes of Decline

Species associations, species richness, metapopulation structure, and densities and population size structure of individual species are all potentially impacted by forest management practices. In addition, any effects on fish communities may ultimately affect mussels as well. Watters (1992) recently found high correlation between fish distribution and diversity and mussel distribution and diversity.

One major cause of mussel declines has been the fragmentation of river drainages through impoundments, channelization and other activities, such as timber-harvesting, which alter flow and sedimentation patterns. Declines in mussel species for various river drainages and the disturbance factor associated with these declines are shown in Table 2.

Timber harvesting operations can have significant effects on both stream water quantity and quality. The influence of catchment vegetation on stream discharge is dependent on a large number of variables, many of which are site-specific. However, in general, removal of forest vegetation increases stream runoff (Campbell and Doeg 1989). Increased flows have the potential to alter the distribution of sediment through scour, flushing, and deposition of newly eroded materials from the banks. Increased flows also have the potential to activate the bed. Bedload movement will wreak havoc on the survival of many mussels, particularly juveniles (Young and Williams 1983). Erosion caused by increased flows at one location results in deposition of this material further downstream. This "zone of aggradation" results in an increased width/depth ratio of that portion of the channel. As width/depth ratios increase the potential for bedload transport also increases. Thus, increased flows cause habitat loss through both sediment deposition and increased bed mobility. In the long term, higher base flow levels and shorter periods between peak flood periods will decrease habitat complexity by preventing the formation of islands, establishment of macrophyte beds, etc. (Frissell 1986). Stabilized sediments, sand bars, and low flow areas, are all preferred unionid habitats (Hartfield and Ebert 1986, Payne and Miller 1989, Stern 1983, Way et al. 1990). It is around these "complex" areas that most mussel beds, and indeed the highest diversity of stream fauna, are found.

Road-building activities and low water crossings associated with logging can lead to the development of "headcuts", or migrating knickpoints in the channel remote from areas of actual modification. Headcuts result in severe bank erosion, channel widening, and depth reduction and can have devastating effects on the mollusc fauna (Hart 1993).

Stream organisms, including mussels, have evolved in rivers that experience seasonal low-flow and high-flow periods (Meador and Matthews 1992). Fluctuating flows, especially if there will be lower flows for long periods of time, will result in the stranding of many mussels. Unlike fish species which can move rapidly in and out of microhabitats with changes in water levels, mussels move very slowly and are unable to respond to sudden drawdowns. Even if stranding doesn't actually kill a mussel, desiccation and thermal extremes will cause physiological stress and may reduce reproductive potential (McMahon 1991).

Fluctuating flows also mean that transport of particulates will vary. Depending on the flow schedule and the materials normally transported in the water column, there is the potential for loss of organics which are the food base for mussels.

Flow alteration not only has the potential to profoundly affect the stream fauna, but riparian fauna as well. Flood waters that normally recharge soils and aquifers may be rapidly exported

Table 2. — Reported loss of unionid mussel species from rivers and factors contributing to the losses.

Drainage	% Species Lost	Major Factor in Decline	Source
Upper Tennessee River	36%	Impoundments, sedimentation	Starnes and Bogan (1988)
Middle and Lower Tennessee R.	13%	Impoundments, channelization, sedimentation	Starnes and Bogan (1988)
Tombigbee River at Epes, AL	68%	Impoundment	Williams et al. (1992)
Stones River, TN	40%	Impoundment	Schmidt et al. (1989)
Upper Stones River, TN	25%	Gravel dredging, water quality	Schmidt et al. (1989)
Sugar Creek, IN	20%		Harmon (1992)
Illinois River, IL	51%	Impoundments, channelization, sedimentation	Starret (1971)
Kankakee River, IL	25%	Siltation	Suloway (1981)
Kaskaskia River, IL	38%	Siltation (80% reduction in numbers of individuals)	Suloway et al. (1981)
Vermillion River, IL	40%		Cummings (1991)
Embarras River, IL	39%		Cummings (1991)
Little Wabash River, IL	24%		Cummings (1991)

downriver. Lowered water tables may cause shrinkage of the riparian corridor and shifts in terrestrial species composition (Allan and Flecker 1993, Smith et al. 1991).

Mussels are most successful where water velocities are low enough to allow sediment stability but high enough to prevent excessive siltation (Salmon and Green 1983, Way et al. 1990). Thus, well-oxygenated, coarse-sand and sand-gravel beds comprise optimal habitat (McMahon 1991). Sediment deposition not only removes or moves habitat, but also clogs mussel siphons (i.e. smothers them) and interferes with feeding and reproduction (Dennis 1984, Aldridge et al. 1987). In addition, because mussels are sedentary filter-feeders, they are particularly sensitive to changes in water quality (Havlik and Marking 1987).

Demographic Consequences

Because of this dependence on the appropriate substrate and flow conditions, freshwater mussels are already naturally patchily distributed in rivers. Fragmentation acts to increase patchiness and to increase the distance between patches. These effects may have major consequences for the metapopulation (i.e. local or subpopulations connected by infrequent dispersal) structure of mussel species, particularly rare species and those with narrow fish-host requirements (Vaughn 1993). As some subpopulations are eliminated and dispersal distances are increased between other subpopulations, demographic and genetic constraints will diminish the ability of mussels to respond to even natural stochastic events much less human-induced environmental change (Wilcox 1986, Murphy et al. 1990).

Forest Management Strategies

Managing forests to maintain fully functional riverine ecosystems is the best way to protect unionid populations in National Forests. Best land-use practices should strive to maintain an uncut riparian corridor at least as wide as the predicted 100 year channel meander (Boon et al. 1992). Forest managers should seek to minimize the use of biocides and encourage selective logging rather than clear-cutting whenever possible. Disturbances such as low-water crossing which were thought to have temporary effects are now known to have long-term detrimental effects on mussel populations through the formation of migrating headcuts. Managing forests from an ecosystem perspective must include long-term monitoring of unionid populations.

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Appendix 1. Species of snails in the family Hydrobiinae included in this study and the sources of information used.

Apachecoccus arizonae	AZ	Arizona Heritage Data Management System 1993, Hershler and Landye 1988, Landye 1973, Taylor 1987
Aphaostracon asthenes	FL	Florida Natural Areas Inventory 1993, Thompson 1984
Aphaostracon monas	FL	Florida Natural Areas Inventory 1993, Thompson 1984
Aphaostracon pycnus	FL	Florida Natural Areas Inventory 1993, Thompson 1984
Aphaostracon theiocrenetus	FL	Florida Natural Areas Inventory 1993, Thompson 1984
Aphaostracon xynoelictus	FL	Florida Natural Areas Inventory 1993, Thompson 1984
Cincinnatia helicogyra	FL	Florida Natural Areas Inventory 1993, Thompson 1984
Cincinnatia mica	FL	Florida Natural Areas Inventory 1993, Thompson 1984
Cincinnatia monroensis	FL	Florida Natural Areas Inventory 1993, Thompson 1984
Cincinnatia parva	FL	Florida Natural Areas Inventory 1993, Thompson 1984
Cincinnatia ponderosa	FL	Florida Natural Areas Inventory 1993, Thompson 1984
Cincinnatia vanhyningi	FL	Florida Natural Areas Inventory 1993, Thompson 1984
Cincinnatia wekiwae	FL	Florida Natural Areas Inventory 1993, Thompson 1984
Pyrgulopsis aardahli	CA	California Natural Heritage Division 1993, Hershler 1989
Pyrgulopsis bacchus	AZ	Arizona Heritage Data Management System 1993, Hershler and Landye 1988
Pyrgulopsis bruneauensis	ID	Idaho Conservation Data Center 1993, Mladanka 1992
Pyrgulopsis chupaderae	NM	National Museum Natural History collections, Mehlhop (personal observation), Taylor 1987
Pyrgulopsis conicus	AZ	Arizona Heritage Data Management System 1993, Hershler and Landye 1988
Pyrgulopsis crystalis	NV	Hershler and Sada 1987, Nevada Natural Heritage Program 1993
Pyrgulopsis davisi	TX	Taylor 1987, Texas Parks & Wildlife Department 1993
Pyrgulopsis deserta	AZ, UT	Arizona Heritage Data Management System 1993, Hershler and Landye 1988, Utah Natural Heritage Program 1993
Pyrgulopsis erythopoma	NV	Hershler and Sada 1987, Nevada Natural Heritage Program 1993
Pyrgulopsis fairbanksensis	NV	Hershler and Sada 1987, Nevada Natural Heritage Program 1993
Pyrgulopsis gilae	NM	Mehlhop (1992, personal observation), Taylor 1987
Pyrgulopsis glandulosus	AZ	Arizona Heritage Data Management System 1993, Hershler and Landye 1988
Pyrgulopsis isolatus	NV	Hershler and Sada 1987, Nevada Natural Heritage Program 1993
Pyrgulopsis merriami	NV	Nevada Natural Heritage Program 1993
Pyrgulopsis metcalfi	TX	Taylor 1987, Texas Parks & Wildlife Department 1993
Pyrgulopsis montezumensis	AZ	Arizona Heritage Data Management System 1993, Hershler and Landye 1988, Landye 1973
Pyrgulopsis morrisoni	AZ	Arizona Heritage Data Management System 1993, Hershler and Landye 1988
Pyrgulopsis nanus	NV	Hershler and Sada 1987, Nevada Natural Heritage Program 1993
Pyrgulopsis neomexicanus	NM	Federal Register 1991a, Taylor 1987
Pyrgulopsis nevadensis	NV	Nevada Natural Heritage Program 1993
Pyrgulopsis n. sp.	NM	Mehlhop (1992, personal observation)
Pyrgulopsis owenensis	CA	California Natural Heritage Division 1993, Hershler 1989
Pyrgulopsis pecosensis	NM	Mehlhop (1992), Landye 1973, Taylor 1987
Pyrgulopsis pisteri	NV	Hershler and Sada 1987, Nevada Natural Heritage Program 1993
Pyrgulopsis perturbata	CA	California Natural Heritage Division 1993, Hershler 1989
Pyrgulopsis roswellensis	NM	Mehlhop (1992), Landye 1973, Taylor 1987
Pyrgulopsis simplex	AZ	Arizona Heritage Data Management System 1993, Hershler and Landye 1988, Landye 1973
Pyrgulopsis solus	AZ	Arizona Heritage Data Management System 1993, Hershler and Landye 1988
Pyrgulopsis thermalis	NM	Mehlhop (1992), Taylor 1987
Pyrgulopsis thompsoni	AZ, MX	Arizona Heritage Data Management System 1993, Hershler and Landye 1988, Landye 1973
Pyrgulopsis trivialis	AZ	Arizona Heritage Data Management System 1993, Hershler and Landye 1988, Landye 1973
Tryonia adamantina	TX	Taylor 1987, Texas Parks & Wildlife Department 1993
Tryonia alamosae	NM	Landye 1973; Mehlhop, P. personal observation, New Mexico Natural Heritage Program 1993, Taylor 1987
Tryonia angulata	NV	Hershler and Sada 1987, Nevada Natural Heritage Program 1993
Tryonia brunei	TX	Taylor 1987, Texas Parks & Wildlife Department 1993
Tryonia cheatumi	TX	Taylor 1987, Texas Parks & Wildlife Department 1993
Tryonia elata	NV	Hershler and Sada 1987, Nevada Natural Heritage Program 1993
Tryonia ericae	NV	Hershler and Sada 1987, Nevada Natural Heritage Program 1993
Tryonia gilae	AZ	Arizona Heritage Data Management System 1993, Hershler and Landye 1988, Landye 1973, Taylor 1987
Tryonia kosteri	NM	Landye 1973, Mehlhop, P. 1992, New Mexico Natural Heritage Program 1993, Taylor 1987
Tryonia margae	CA	Hershler 1989
Tryonia quitobaquitae	AZ	Arizona Heritage Data Management System 1993, Hershler and Landye 1988
Tryonia rowlandsi	CA	Hershler 1989
Tryonia salina	CA	Hershler 1989
Tryonia stocktonensis	TX	Taylor 1987, Texas Parks & Wildlife Department 1993
Yaquicoccus bernardinus	AZ	Arizona Heritage Data Management System 1993, Hershler and Landye 1988, Taylor 1987

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THE Nature Conservancy
ARKANSAS FIELD OFFICE

9 September 1994

Jerry Brabander/Field Supervisor
Fish and Wildlife Service
Ecological Services
222 S. Houston, Suite A
Tulsa, OK 74127

Dear Mr. Brabander:

Thank you for the opportunity to review the draft Ouachita Rock-pocketbook Recovery Plan. The plan as written is reasonable and doable and appears to have a good chance of leading to the recovery of the Ouachita Rock-pocketbook. The Conservancy fully supports its implementation and offers its services to the recovery effort. Specific comments follow:

1. The Corps of Engineers' regulation of water releases from the Sardis Dam appear to be negatively impacting reproduction of downstream mussel populations. Firm scientific evidence is lacking but it should be possible to work with the Corps to achieve a more "natural" flow regime while simultaneously researching the life history and habitat requirements of the Ouachita Rock-pocketbook. 41

2. Task 1.25, the development of a strategic habitat protection plan for the Kiamichi should also be a number one priority. Biologically the Kiamichi River is one of the most diverse in the United States. High numbers of resident fish and mussel species, many of which are declining throughout their ranges, as well as consistent water quality make the Kiamichi a river system of high protection priority. An ecosystem approach to maintaining this biologically rich system is appropriate. 42

3. Will there be an attempt to delineate critical habitat areas? 43

4. While the negative impacts of gravel mining are mentioned in the plan it may deserve more emphasis. Much of the mining seems to be carried out by local and state agencies which should need permits for these activities. 44

Sincerely,

Douglas Zollner

Douglas Zollner/Project Manager
Ouachita Mountains Conservation Initiative

The Nature Conservancy 601 North University Avenue / Little Rock, Arkansas 72205 / (501) 663-6699 FAX (501) 663-8332
International Headquarters / 1815 Lynn Street / Arlington, Virginia 22209
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Little River Conservation District

Federal Building, Rm. 124 - 201 N. Central - Idabel, OK 74745 - Phone (405) 286-SOIL (7645)

Sept. 9, 1994

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Jerry J. Brabander
U. S. Fish & Wildlife
222 South Houston, Suite A
Tulsa, OK 74127-8909

Dear Mr. Brabander,

On behalf of the Board of Directors of the Little River Conservation District, I would like to make the following request of the U. S. Fish and Wildlife Service, concerning the Ouachita Rock-Pocketbook Recovery Plan.

Since the Little River Basin contains all of the alleged Ouachita Rock-Pocketbook Mussel habitat; and since a large portion of this area lies within the boundaries of the Little River Conservation District. The Board of Directors in accordance with the Endangered Species Act; request that you hold a public meeting within the boundaries of said District for the purpose of reviewing historical records on the Ouachita Rock-Pocketbook and answering any questions that local citizens may have.

45

46

Sincerely,

Frank Acker

Frank Acker, Manager
Little River Conservation District

PATRICIA P. EATON
EXECUTIVE DIRECTOR

DAVID WALTERS
GOVERNOR

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STATE OF OKLAHOMA

WATER RESOURCES BOARD

September 12, 1994

Jerry J. Brabander
Field Supervisor
U.S. Fish & Wildlife Service
Ecological Services
222 S. Houston, Suite A
Tulsa, OK 74127

Dear Mr. Brabander:

We have reviewed your draft recovery plan for the Ouachita Rock-pocketbook Mussel and are currently developing formal comments which should be completed later this week. I ask that you allow us this short extension of time so that our position on this plan may be considered for inclusion in the final document. 47

As you know, the continued viability of the Ouachita Rock-pocketbook Mussel in Oklahoma is important to the Water Resources Board. We appreciate your efforts to ensure the survival of this species.

Sincerely,

Mike Mathis

Mike Mathis, Chief
Planning Division

600 N. HARVEY AVE. • P.O. BOX 150 • OKLAHOMA CITY, OKLAHOMA 73101-0150 • TELEPHONE (405) 231-2500 • FAX (405) 231-2600

PATRICIA P. EATON
EXECUTIVE DIRECTOR

DAVID WALTERS
GOVERNOR

STATE OF OKLAHOMA
WATER RESOURCES BOARD

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September 19, 1994

Jerry J. Brabander
Field Supervisor
U.S. Fish & Wildlife Service
Ecological Services
222 S. Houston, Suite A
Tulsa, OK 74127

Dear Mr. Brabander:

RE: Ouachita Rock-Pocketbook Draft Recovery Plan

As you know, the continued viability of the Ouachita Rock-pocketbook Mussel in Oklahoma is important to the Oklahoma Water Resources Board. We sincerely appreciate your efforts to ensure the survival of this species.

Thank you for granting us a short extension of time to formally comment. We have reviewed the Draft Recovery Plan, submitted to the OWRB on August 10, 1994. After review, we have identified several concerns regarding the Draft Recovery Plan and these are enclosed in Attachment A.

If you have any questions concerning our comments, please feel free to write or call me at (405)231-2551.

Sincerely,

Duane A. Smith

Duane A. Smith, Assistant Director
Oklahoma Water Resources Board

Attachment

600 N. HARVEY AVE. • P.O. BOX 150 • OKLAHOMA CITY, OKLAHOMA 73101-0150 • TELEPHONE (405) 231-2500 • FAX (405) 231-2600

Attachment A
Comments regarding the Ouachita Rock-Pocketbook Draft Recovery Plan

by
Oklahoma Water Resources Board
September 19, 1994

In short, the Oklahoma Water Resources Board has several concerns regarding the Draft Recovery 48
Plan for the Ouachita Rock-Pocket Book Mussel. The OWRB believes that reservoir control has the potential of being beneficial to the survival of the mussel. Additionally, we believe that reservoir control would help stabilize flows, prevent scouring of the river bed and reduce sediment levels within the stream system below the reservoir. Although reservoir control has a potential to create problems (such as isolation between populations above and below the reservoir), the OWRB feels that the advantages of reservoir control may prove to out weigh the disadvantages associated with reservoir control.

Additionally, it is obvious from the contents of the document, further detailed studies of the mussel 49
(including its reproduction patterns, susceptibility to change within its environment, life cycle and habitat requirements) should be conducted prior to the finalization of any recovery plan and expenditure of literally hundreds of thousands of dollars toward implementation of such a plan.

Specific Comments:

1. Page 10. The OWRB believes that reservoir control has the potential to help stabilize the 50
fluctuating flows of the Kiamichi. We also believe that reservoir control will help prevent scouring to the river bed during periods of high flow (i.e. flooding) and would also help reduce sediment levels. Flow for the Kiamichi River is known to range from multi-thousand CFS to near zero, during low flow months.

2. Page 12. The OWRB is concerned with the notion of determining reproduction without the 51
process somehow affecting existing populations.

3. Page 13. According to the text on the preceding page 13, stable flows are important to mussel 50
survival. It should be noted that reservoirs will help stabilize flows through controlled releases. Therefore, reservoir control has the potential to be beneficial to the existence of the mussel.

4. Page 15. Impoundments do have the potential to disrupt fish species acting as hosts for the 52
mussel larvae, but in what manner does siltation/sedimentation damage the species? Is it true that impoundments actually trap and hold sediment, rather than allow its passage downstream (into the mussel habitat) as could be caused by activity in the stream/river?

5. Page 16. In reference to all available evidence indicating that the Ouachita rock-pocketbook 53
does not tolerate certain changes, it may be helpful to know what the available evidence is or where to find it.

6. Page 17. More information is needed to back up the comment concerning the potential existing 54
for very serious damage to mussels from Broken Bow reservoir, even to the point of eliminating the Little River Ouachita Rock-pocketbook population.

7. Page 18. Here, a somewhat positive study is dismissed due to insufficient data. If this is 55
accepted, then the other data throughout this report also appears pretty thin/insufficient to support the proposed conclusions/recommendations.

8. Page 19. The document now suggests that impacts are predictable even though previous pages 56
indicate there is not enough information available.

9. Page 20. Have there been any studies regarding exposure time and frequency? It would be 57
interesting to see some numbers.

10. Page 23. There seems to be some disagreement as to whether or not development of 58
hydropower facilities at Sardis Reservoir would degrade conditions within the Kiamichi River. Could a low-level hydropower project operate in a manner that would not degrade current conditions or influence the Ouachita Rock-Pocketbook mussel?

11. Page 24. The OWRB is concerned with the following statement: "Although the ultimate 59
biological impact cannot be predicted, evidence indicates these mussels will eventually infest most North American drainage south of central Canada and will interfere with normal feeding and movements of native mussels, sufficient to seriously reduce native mussel populations." We believe this scenario is highly unlikely and our reasons are as follows: water in Southeast Oklahoma is too warm; 2) conductivity/hardness is too low and; 3) salinity in the Red River Basin is too high.

12. Page 26. Additional explanation is needed to expand upon the informal "Service" consultation 60
with the U.S. Army Corps of Engineers regarding the operation of Sardis Reservoir.

13. Page 56. The questions that must be asked is how can any species receive additional protection 61
until one knows it's habitat requirements and limiting factors (i.e. if mussels are limited by sedimentation, augmenting larval host populations or limiting discharges would have no effect).

UNITED STATES GOVERNMENT

memorandum

DATE: September 26, 1994

REPLY TO ATTN OF: Chief, Division of Endangered Species, FWS, Atlanta, Georgia (AES/TE)

SUBJECT: Ouachita Rock-pocketbook Draft Recovery Plan

TO: Field Supervisor, FWS, Tulsa, Oklahoma (Attn: Alan David Martinez)

Supervisor	
Assistant	
Adornato	
Aldrich	
Brubeck	
Collins	
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Hensley	
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We have reviewed the subject draft plan as requested. We only have a few comments to offer and these are provided below.

Executive Summary

Recovery Criteria - We suggest using the term "reclassification" to threatened status instead of "upgrading" throughout the recovery plan. How feasible is deauthorizing the Tuskahoma Reservoir? 62

Part I. Introduction

Page 24, second paragraph - Suggest restructuring the third sentence to "That study is designed to determine Ouachita rock-pocketbook occurrence in different river microhabitats. Movement, growth, survival, population fluctuations, and relative influence of water pollution and impoundment on mussel populations are also being examined." 63

Page 26, second paragraph - Would deauthorization of the proposed Tuskahoma Reservoir be a reasonable and prudent alternative? 64

Page 27, first paragraph - What do you mean by "unintended circumstances" in the fourth sentence? 65

Part II. Recovery

Page 31, third paragraph - Recommend rewording the last sentence to "The estimated date for reclassifying the species to threatened is 2015, if recovery criteria are met." 62

Page 32, fourth paragraph - Change "between" to "among" in the third sentence. 66

Page 36, second paragraph - What are some examples of the "additional measures" needed to achieve basic protection of the Kiamichi River population? What are 67

OPTIONAL FORM NO. 10
(REV. 1-80)
GSA FPMR (41 CFR) 101-11.6
5010-114

*U.S. GPO: 1993-342-199/60133

the limited authorizations that may exist? Development of a habitat conservation plan for an incidental take permit is still a requirement of the Endangered Species Act.

Page 37, first paragraph - We recommend changing this 68
task to "Evaluate the feasibility of deauthorizing the Tuskahoma Reservoir" and suggest working with the Corps of Engineers (Corps) in finding a reasonable and prudent solution.

Page 51, first paragraph - Again, we recommend renaming and changing this task to show that the Fish and Wildlife Service will work with the Corps to implement feasible recovery actions.

Page 64, second paragraph - This task can also be 69
implemented through partnerships with universities, private contractors, or the American Zoo and Aquarium Association. We suggest adding these to the list of responsible parties in the Implementation Schedule for this task and task 9.62.

Page 65, second paragraph - Suggest adding "in 70
perpetuity" at the end of the last sentence.

We appreciate the opportunity to review this recovery plan. If you have any questions regarding our comments, please contact Gloria Lee of my staff at 404/679-7100.

David P. Flemming

OKLAHOMA

DAVID WALTERS, GOVERNOR
GREG D. DUFFY, DIRECTOR

DEPARTMENT OF WILDLIFE CONSERVATION

1801 N. Lincoln P.O. Box 53465 Oklahoma City, OK 73152 PH. 521-3851

September 29, 1994

Mr. David Martinez
U.S. Fish and Wildlife Service
222 South Houston, Suite A
Tulsa, OK 74127-8909

Dear Mr. Martinez,

This responds to the draft Ouachita Rock-pocketbook Recovery Plan prepared by your office and distributed for review on August 8, 1994. The draft recovery plan has been reviewed by the Natural Resources Section and Fisheries Division of the Oklahoma Department of Wildlife Conservation; however, no coordinated response has been prepared. This letter reflects the comments of the Natural Resources Section. If you do not receive a response from ODWC's Fisheries Division, please assume they have no additional comments.

We have reviewed the draft recovery plans and have no objections to its findings or approach. We concur with the need for each of the stated recovery tasks and will cooperate with the Service to accomplish these tasks to the best of our capability. 71

We appreciate the opportunity to review and provide comments on this draft. If you have any questions, please feel free to contact the Natural Resources Office at (405) 521-4616.

Sincerely,

Mark D. Howery

Mark D. Howery
Natural Resources Biologist

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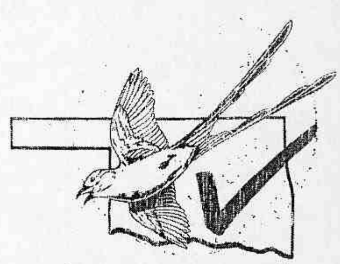

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WASHINGTON, D.C. 20460

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U.S. Fish and Wildlife Service
Division of Endangered Species
Recovery Coordinator
P.O. Box 1306
Albuquerque, NM 87103

Dear Sir:

Thank You for sending us a copy of the Ouachita Rock-pocketbook *Arkansia wheeleri* Ortmann and Walker, 1912 Draft Recovery Plan for review and comment.

Ecological Effects Branch has reviewed the draft document. It appears to be a conscientiously developed recovery plan for this endangered mollusk. We have no specific comments or questions at this time. 72

Sincerely,

Douglas Urban, Deputy

for Antony F. Maciorowski, Chief
Ecological Effects Branch
Environmental Fate and Effects Division (7507C)

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SUMMARY OF FWS RESPONSES TO COMMENTS ON THE FIRST DRAFT RECOVERY PLAN FOR THE OUACHITA ROCK POCKETBOOK

Eugene C. Gregory

1. The commenter expressed concern for possible persisting effects on organisms (such as the Ouachita rock pocketbook) inhabiting the Little River basin, from past activities at a former fiberboard plant. It is possible for such effects to occur, either from residual pollutants continuing to exert adverse effects (Ahlstedt and Tuberville 1997), or from biological factors (e.g., limited mobility, delayed maturation, low recruitment of offspring, and high juvenile mortalities) constraining mussels or other species so that many years are required to reestablish and rebuild damaged populations (McMahon 1991, Vaughn and Taylor 1999).

   Although it is difficult at this point to evaluate events described by the commenter, the facility in question is known to have operated for many years under relatively lax (by today's standards) waste management requirements, was sold in 1969 by the owners who would have been responsible for the alleged practices, and drew attention from jurisdictional agencies on multiple occasions for attributed environmental effects and/or apparent violations of applicable requirements. The U.S. Environmental Protection Agency (EPA) evaluated the facility under CERCLA (the Comprehensive Environmental Response, Compensation and Liability Act, aka Superfund) in the early 1980's, but found that persisting risks did not warrant further action under that program (Jhana Enders, EPA, *in litt.* 2001). Production operations at the facility ceased in 1990, and the current owner (Weyerhaeuser Co.) has continued working with the Oklahoma Department of Environmental Quality (ODEQ) to address waste management needs on the subject property. A former landfill at the site has been capped; continuing activities include use of monitoring wells to identify possible leaks from the landfill, eventual closure of former waste treatment lagoons on the property, and interim compliance with an NPDES (National Pollutant Discharge Elimination System) permit issued for the lagoons (Kelly Dixon, ODEQ, *in litt.* 2001, Mike Wood, Weyerhaeuser Co., pers. comm. 2002). Biological data from localities downstream from the facility indicate degraded conditions, but other local influences (e.g., cold, irregular reservoir releases) appear more severe than any residual pollution likely issuing from the former fiberboard plant. As recovery of the Ouachita rock pocketbook is pursued, future research and management efforts (e.g., under Tasks 3.1, 3.2, 3.3, and 5) may include more detailed assessments of factors affecting the lower Mountain Fork River, possibly better discerning effects attributable to reservoir operations, area pollution sources, and other causes. These tasks also call for treatment of factors found to interfere with the recovery of *Arkansia wheeleri.*

2. Recent surveys of the Little River system have included localities in the Little River shortly above the Mountain Fork River confluence, in the reach above Yanubbee [Crooked] Creek, and elsewhere (see references discussed under Distribution and Abundance). These have verified the Ouachita rock pocketbook's recent occurrence in the Little River as far west as Wright City, and as far east as near Millwood Reservoir, although the species' occurrence through most of that river section is limited and sporadic, due to habitat degradation.

3. The commenter's opinions notwithstanding, many scientific studies have documented potentials for gravel excavation and dam construction to harm aquatic life and modify native aquatic communities, including mussels and fish (see references discussed under Reasons for Listing/Threats). Because tolerant species can exploit many such disturbances, effects can be subtle and remain undetected without scientific investigation. At the same time, gravel excavation can be performed in ways that minimize effects on stream life, and small, low-head dams do not produce the full range and scale of effects produced by large dams. If the gravel mine mentioned truly has not been detrimental to aquatic life, it is most likely due to its operation in an environmentally conscientious manner.

4. The described pollution of the Rolling Fork River is discussed in the recovery plan as a known threat (see Water quality degradation) and has been noted, in fact, by multiple survey crews. Treatment of residual contamination from the spill, and of other pollution affecting the stream, has been initiated. Tasks 3.1, 3.23, and 9.3, among others, call for adequate treatment of pollution sources potentially affecting the Ouachita rock pocketbook and its existing/former habitats.

Dianna F. Noble, Texas Department of Transportation

5. Agency references in the plan have been changed to use the requested abbreviation.

6. The cost shown for the agency was an FWS estimate of average annual expenses. Like other cost estimates appearing in the plan, the level was developed using a variety of considerations, such as portion of the species' range within the state, relevant facilities and activities, task priority and total duration (extending, as in most cases, beyond the three years shown), and findings of others planning or implementing similar recovery tasks for other species. Because of considerable uncertainties regarding recovery of *A. wheeleri* and prevailing economic conditions at the time of specific actions, actual costs will likely differ from those listed, which were intended as general approximations only. Task costs listed in the recovery plan neither commit nor limit recovery participants to actual expenditures, which will be more accurately estimated as specific tasks are pursued.

7. It is appropriate for the Texas Department of Transportation to consult with the Arlington Ecological Services Field Office in matters regarding the Ouachita rock pocketbook. In occasional instances (e.g., involving formal consultations or take permits), the Arlington office may seek assistance from other FWS offices or suggest the Department contact such offices directly.

Bob Howells, Texas Parks and Wildlife Department

8. The plan has been revised to reflect the additional record.

9. The FWS agrees that survival of *A. wheeleri* and associated organisms in Sanders Creek could be enhanced by managing reservoir releases to maintain favorable conditions for the species. As indicated, Pat Mayse Reservoir was built and is operated by the U.S. Army Corps of Engineers (CE). The Endangered Species Act requires federal agencies such as the CE to ensure that they

do not jeopardize the continued existence of listed species, and further authorizes them to actively conserve such species. These considerations will be applied to Pat Mayse Reservoir under tasks 3.1 and 3.22 of the recovery plan, with input from tasks 4.1 and 5. As release recommendations are developed and revised, the relevant (Tulsa) CE district will ensure that project personnel receive information and approval by which to implement those recommendations.

David E. Bowles, Texas Parks and Wildlife Department

10. The plan has been revised to reflect the additional record.

11. The plan has been revised to reflect designation of the Texas streams as mussel sanctuaries.

Richard W. Standage and Larry D. Hedrick, Ouachita National Forest

12. The FWS subsequently received a copy of the project report, which did indeed report no evidence of the Ouachita rock pocketbook from tributaries on the Tiak Ranger District. Task 2.3 has been revised within the plan and implementation schedule to reflect completion of this responsibility by the Ouachita National Forest.

13. The FWS appreciates the interest of the Ouachita National Forest in supporting projects to benefit recovery of the Ouachita rock pocketbook. The FWS will notify the Forest of further opportunities to participate in such efforts, as these are submitted by cooperators for our consideration.

Caryn C. Vaughn, Oklahoma Natural Heritage Inventory

14. The plan has been updated as suggested to reflect more recent records from the Little River, including surveys completed later in 1994.

15. The introduction has been revised to include possible confusion with the threeridge, *Amblema plicata*, and basic means of distinguishing typical specimens.

16. The plan has been revised to reflect this additional record from the Kiamichi River.

17. The plan's discussion of habitat has been revised to reflect both the extracted description and the manuscript analyses, later published as Vaughn and Pyron (1995).

18. The habitat discussion has been revised to include the possibility that early habitat descriptions mischaracterized substrates in which specimens of *A. wheeleri* were found, in the context of current standards for sampling and classification.

19. Some of this information was covered in the paragraphs preceding the two specified. The plan has been revised to reflect other information provided, such as efforts to identify probable fish hosts.

20. The discussion of effects related to impoundment and channelization has been revised, and includes reference to available studies on the Little River. Those studies help substantiate the apparent sensitivity of the Ouachita rock pocketbook to stream modifications produced downstream from dams.

21. The discussions of effects observed downstream from Pine Creek Reservoir have been revised to incorporate later surveys, and include effects attributed to coldwater releases and the sawmill near Wright City (actually a timber/plywood mill, the company's local paper mill being located at Valliant and discharging into Garland Creek).

22. The plan has been revised to incorporate (in paraphrased form) this later comparison of localities upstream and downstream from Sardis Reservoir, using numbers of inhabited localities; abundances of *A. wheeleri*; recruitment by a more common, surrogate species; and glochidial densities.

23. While this concern has been expressed, many mussel populations seeming to exhibit such characteristics may face better than expected chances for survival. Many species appear to be relatively long-lived, and some of those examined do not exhibit senescence, showing a continued increase in reproductive output with age. Failure to recruit significant numbers of juveniles during certain years may be normal among some populations, and surviving juveniles are typically difficult to detect for the first few years. Nevertheless, the Ouachita rock pocketbook is not known to possess such traits, and any potential loss of reproduction is a point of concern, given the species' endangered status.

24. The stranding episode described was summarized in the draft plan, based on the account of Vaughn and Pyron (1992). Additional information pertaining to effects from flow modifications has been incorporated into the approved plan, including further observations in the Kiamichi River below Jackfork Creek.

25. Post-impoundment changes in the quantity and composition of particles transported by streams (including items used as food by mussels) has been documented for some drainages, and hypothesized as a possible effect on the Kiamichi River (Mehlhop and Miller 1989). A general potential for such change is mentioned in the recovery plan. Specific changes are not known to have been evaluated for streams within the natural range of *A. wheeleri*, but can be reasonably assumed to have occurred. The significance of such changes to the species is unknown.

26. Increased flows can indeed cause the indicated conditions, and like other flow modifications potentially associated with dams and diversions, can change aquatic communities dramatically by affecting species sensitive to the change in conditions. Substrate qualities are among the most significant factors determining freshwater mussel distribution, and loss of channel stability/increased sedimentation are probably detrimental to most mussel species. The plan's discussion of such effects has been expanded, including a description of channel changes detected below the confluence of Jackfork Creek and the Kiamichi River.

27. The plan has been revised to note the role of natural flows in formation and maintenance of complex habitats important to the occurrence of many mussels and other stream species.

28. The plan has been revised to note the important ecological relationships existing between streams and riparian zones, the corresponding importance of riparian zones to stream conservation (and vice versa), and the inordinate susceptibility of those zones to disturbance.

29. The isolation effect of reservoirs is considered in the plan, although not described at the level of detail provided by the commenter. While the plan is meant to be comprehensive, it is necessary to briefly treat most subject matter covered, while providing references to further information. In this case, and some others, it was felt that the recovery plan adequately covered commenters' issues or technical points, without discussion at the length requested. While not always requested by a given commenter, raised issues or points often receive additional consideration in the development of individual recovery tasks, such as 6.1 and 6.2, which include analysis of population isolation. Regardless, the full comments of commenters remain available in this appendix.

30. The plan has been revised to note important ecological relationships existing between streams and surrounding landscapes. The modification of natural cover can produce a wide range in stream effects, dependent on many variables (as stated).

31. "Headcuts" are a legitimate concern in conserving aquatic mollusks, and can be caused by activities other than construction of roads and crossings. Other activities commonly initiating headcuts include gravel mining, channelization projects, and smaller cuts to bypass stream meanders. One of the most significant effects from headcutting on the benthic fauna results from essentially a total disruption of the stream bottom at the moving point of the cut.

32. The plan is felt to cover this material adequately.

33. Likewise, predation was not identified as a threat during listing of *A. wheeleri* as an endangered species (Martinez and Jahrsdoerfer 1991).

34. The FWS considers the zebra mussel to be a serious threat to the Ouachita rock pocketbook, though not an immediate one. The plan's discussion of this threat has been expanded to highlight likely invasion routes into the range of *A. wheeleri*, as priority points for applying preventive measures.

35. Sardis Dam includes capabilities for both surface and subsurface releases, and both are used. The FWS has conducted preliminary evaluations of releases from Sardis Reservoir, and found that these are sometimes significantly cooler than acclimated water in the downstream channel. Such releases can abruptly and markedly reduce temperatures in the creek, although extent of effect in the Kiamichi River has not been determined. Degree of threat to *A. wheeleri* from existing or hypothetical releases is currently unknown, but warrants research and management attention under Tasks 5.3and 1.1.

36. The recommended parameters have been added to Task 1.31.

37. DNA fingerprinting has been added as a technique specifically listed under Task 4. While the

FWS agrees with the distinct utility of that technology, certain obstacles exist to its potential application to *A. wheeleri*, several of which the commenter mentions. To the list could be added the normal rarity of *A. wheeleri*, by which its glochidia would be expected to comprise a very small fraction of combined glochidial populations. The FWS appreciates the offer of adult tissue and glochidia samples for genetic analysis.

38. It would be necessary to obtain juveniles from infested fish known to be free of infestation from other indistinguishable species. While culture of the fish would be necessary, it might be possible to bring gravid *A. wheeleri* into the lab for only the period necessary to release active glochidia. Similarly, transformed juveniles might be returned to the wild in very fine-mesh enclosures where their success in different microhabitats could be monitored. Alternatively, successful development of culture techniques would allow more of this work to be performed in the lab. Clearly, there are many pre-requisite steps to either approach, and the task would probably follow other priority 1 tasks.

39. Work to date has produced much useful information about microhabitats successfully occupied by the Ouachita rock pocketbook. While these have been contrasted with other microhabitats available nearby in the same system, and affinities exhibited by other species, studies have not examined broad-scale variables that might potentially correspond with *A. wheeleri* incidence among streams or stream segments (e.g., as in Strayer 1993, Strayer *et al.* 1994, Di Maio and Corkum 1995). In addition, studies have not yet defined actual environmental sensitivities (i.e., responses and tolerances) of the Ouachita rock pocketbook to variable conditions. Environmental factors (e.g., temperatures) varying to extreme levels can produce stress in mussels and other organisms prior to reaching lethal levels. Relatively non-injurious techniques exist (e.g., tissue glycogen analysis) that indicate degrees of stress (Naimo *et al.* 1998, Naimo and Monroe 1999). Knowledge of stress levels produced under varied conditions would be valuable to management decisions dealing with water quality standards development, reservoir operations, instream and nearstream construction, for example. The task has been partly rewritten to better explain its value.

40. The Freedom of Information Act (FOIA) allows certain information (e.g., data divulging precise locations of threatened or endangered species occurrences) to be exempted from FOIA requests, as sensitive information. This is in recognition of the fact that full release of such information might subject listed species to increased harm.

<u>Doug Zollner, The Nature Conservancy Arkansas Field Office</u>

41. The CE has shown an interest in modifying releases from Sardis Reservoir to accommodate needs of the Ouachita rock pocketbook, while meeting other project purposes. This is perhaps most clearly indicated by the CEs' agreement to begin special releases in September 2000 to relieve extreme drying and heating of downstream mussel beds (discussed in the body of this plan). Through further analysis, the FWS hopes to recommend and arrange for automatic releases to meet minimum flow needs, should similar conditions recur. In addition, the CE has undertaken hydrologic studies to better characterize pre- and post- impoundment flow conditions in Jackfork Creek and the Kiamichi River. When completed, these should give an improved picture of the natural flow regime (Poff *et al.* 1997, Richter *et al.* 1997), and could be used as an

initial basis for restoring key elements of flow.

42. The FWS agrees that development of such a plan for the Kiamichi River is important but believes it should remain a number 2 priority. Current priority 1 tasks include such things as protection of the river under existing law; monitoring of *A. wheeleri*, its habitat and threats; and determination of the species' reproductive biology. Recovery of the Ouachita rock pocketbook would be virtually impossible without pursuing these tasks. While expected to be valuable and effective, development of a strategic habitat protection plan for the Kiamichi River is not equally essential. Advantages might exist to developing such a plan after starting certain other tasks. In the interim, the species' recovery plan can serve as a partial protection plan for the Kiamichi River.

43. Designation of critical habitat was determined to be not prudent at the time *A. wheeleri* was listed as an endangered species (Martinez and Jahrsdoerfer 1991). However, the overall value and prudence of designating critical habitat are issues that can be revisited over time, as circumstances change. At present, the FWS has no particular plans to reconsider critical habitat designation for the Ouachita rock pocketbook.

44. Multiple mussel surveyors have noted gravel mining as an actual or potential threat to *A. wheeleri* and associated species. While not affecting these resources to the degree of some other factors (especially impoundments), the harm produced by gravel mining practices must be addressed to accomplish recovery of the Ouachita rock pocketbook. Opportunities to do this exist within tasks 1.1, 1.24, 1.254, 1.32, 3.1, 3.23, 3.3, 8, and 9.3, among others. Additional information related to gravel mining effects has been added to the recovery plan. The FWS will strive to ensure that implementation efforts include adequate attention to these activities as significant impact sources.

<u>Frank Acker, Little River Conservation District</u>

45. The Ouachita rock pocketbook is known from the Little River basin, but also from the Kiamichi River, Ouachita River, Pine Creek, and Sanders Creek, all separate basins from the Little River watershed. Known localities appear to be shared by the Kiamichi, Little River, Pushmataha, Talihina, and Valliant conservation districts (Oklahoma); the Calhoun County, Clark County, Cossatot, Hot Spring County, Little River County, and Ouachita County conservation districts (Arkansas); and the Lamar Soil and Water Conservation District (Texas).

46. The FWS chose not to hold the requested public meeting, finding it more important at the time to deal with pressing research and management needs, to examine emerging proposals for new water resource development, and to work toward completion of the recovery plan, given limited program resources. Historical records of *A. wheeleri* were reviewed individually in the draft plan and are reviewed again in the approved plan, with the addition of previously unavailable information. The recovery plan calls for development of an outreach program to more effectively communicate with the public regarding the Ouachita rock pocketbook. That program will include opportunities for groups and citizens to meet with FWS specialists.

<u>Mike Mathis, Oklahoma Water Resources Board</u>

47. The requested extension was granted. The comments under development were later received, and follow this letter.

Duane A. Smith, Oklahoma Water Resources Board

48. The FWS agrees that reservoirs can be operated to produce conditions that are compatible with, and sometimes enhance, the survival of native mussels, other riverine organisms, and their habitats downstream from the reservoir structures. However, achieving such benefit can be impeded by (1) operational limitations of a reservoir, e.g., an inability to draw releases from multiple levels within the reservoir and loss of discretionary capacity over time, (2) conflicts between such operation and operation to serve other reservoir management objectives, (3) a lack of sufficient knowledge regarding actions needed to best benefit downstream resources, and (4) a failure to complete the necessary coordination among parties that would translate best available knowledge of biological needs into operational actions at reservoirs. Furthermore, some impacts associated with reservoirs (e.g., environmental changes throughout most of the pool, loss of genetic exchange between upstream and downstream populations) cannot be feasibly mitigated for the full native community by modifying operations. Given the general situation seen in North American freshwater systems today, an instance in which the sum of downstream benefits produced with a reservoir outweighs the associated impacts seems very unlikely, in relation to conserving the native diversity of species and especially sensitive species. In any case, the relative balance of benefits and impacts would vary case-by-case, and would depend on such factors as the extent of favorable actions actually realized, an avoidance of unfavorable actions, and location and reach of reservoir impacts within the ranges of affected species.

49. A need for research to fill information gaps is not a valid reason for postponing finalization of a recovery plan. In fact, identification of a research need within an approved recovery plan typically improves chances of funding a proposal to address that need through the primary funding sources used in listed species conservation. In addition, the term “final” can be misinterpreted here, since approved recovery plans (sometimes referred to as final plans) that normally follow draft plans can be revised or supplemented. The FWS reviews approved recovery plans periodically and may prepare updates or revisions, as tasks are completed, new information collected, and new needs identified. In regards to the Ouachita rock pocketbook, the FWS is issuing an approved plan to promote conservation of the species, but anticipates that periodic revisions will be warranted as knowledge of the species increases and investments are made in its recovery.

50. The FWS agrees that Sardis Reservoir could be operated to partly reduce flow fluctuations, riverbed scouring, sediment suspension, and other conditions generally detrimental to the native mussel fauna. However, difficulties are seen in achieving that potential, amply and soundly, for reasons listed above. Without adequate weighing of resource impacts, reservoir operations often produce new flow fluctuations and channel erosion, typically at unnatural times and places. In addition, certain extreme conditions (flood flows) and forms of instability are probably important in the formation and maintenance of stream habitats, and the occurrence of rare species such as the Ouachita rock pocketbook. Furthermore, consideration must be given to other adverse reservoir effects on stream organisms, which are not addressed by treating flow and sediment issues. These topics are discussed in more detail in revisions to the recovery plan and in some of

the following responses. Regardless, the recovery plan calls for improved management of existing reservoirs to produce the best practicable conditions for *A. wheeleri* (e.g., see Tasks 1.1 and 3.1).

51. Determination of details of reproduction in the Ouachita rock pocketbook is necessary because impaired reproduction may be one of the primary effects expressed under adverse conditions. It is necessary also in case population declines continue to a point where it becomes necessary to apply artificial propagation. However, in studying these aspects, it will be crucial to take steps that absolutely minimize effects on existing populations. Several such steps are identified under Task 4, including non-injurious examinations of individuals, minimal retention of individuals in laboratory facilities, and use of surrogate species to develop techniques, among others. While some stages of this research may involve intended or unintended deaths of *A. wheeleri* individuals, the FWS believes failure to obtain this information would ultimately lead to greater impacts on existing populations.

52. Excess siltation and sedimentation are detrimental to mussels in numerous ways, the more direct avenues including interference with respiration, feeding, and reproduction, processes that all depend upon unimpeded circulation of water through the animals and a proper condition and functioning of the gills. This is discussed in the recovery plan under Water quality degradation, including references to detailed sources. Impoundments do create deep deposits of fine sediments, which relatively few mussel species inhabit, and releases from impoundments generally exhibit a much reduced sediment load. However, sediment loads tend to reduce the energy characteristics of streams, and load reductions correspondingly allow faster flows within a given channel and gradient. As a result, clarified waters released from dams tend to be faster and more erosive until restoring a natural balance between transported load and flow characteristics. Dams can increase downstream erosion and sedimentation in other ways as well. For example, frequent fluctuations in released flows alternately saturate and expose bank soils, promoting sloughing.

53. Evidence indicating *A. wheeleri*'s low tolerance to changes produced downstream from reservoirs is discussed in the recovery plan and includes poor survival/possible elimination within an extended stream section below Pine Creek Dam, a similar status below Little River's confluence with the Mountain Fork River, elimination from the Kiamichi River below Hugo Dam, and reduced frequency and abundance in the Kiamichi River downstream from Jackfork Creek. Discussion in the recovery plan includes reference to detailed sources.

54. Clarke's (1987) statement was probably based on the small size of the Little River population (considered too small for long-term viability), limited effects he observed but failed to emphasize, and a known potential of other impoundments to eliminate sensitive species. Subsequent studies (Vaughn and Taylor 1999) help to back up Clarke's statement. The recovery plan has been revised to mention more of the conditions noted by Clarke and the later investigation by Vaughn and Taylor.

55. The recovery plan attempts to summarize available information, which is sometimes limited, but rarely contradictory. Regarding the section of Kiamichi River downstream from Jackfork Creek, Clarke's assessment, while authoritative, lacked the intensity and specificity of later studies.

Perhaps worth noting is the fact that Clarke's survey occurred close in time to the impoundment of Sardis Reservoir (1983), and certain effects may not have been as evident as in later years.

56. It is possible to predict predominant impacts resulting from water resource development projects, but certainly not the full range and extent of impacts. Because Tuskahoma Reservoir would be located in the heart of the healthiest sub-population of *A. wheeleri* (in the Kiamichi River upstream from Jackfork Creek), and would likely produce downstream effects, the FWS feels confident in predicting its impacts as severe and far-reaching.

57. Numerous studies have controlled exposure time and frequency. The review by Havlik and Marking (1987) includes examples of these.

58. While it is difficult to speak in generalities, addition of a low-level hydropower facility would add another management objective at Sardis Reservoir to be considered while trying to provide for the Ouachita rock pocketbook. Ability to meet both objectives would typically be determined during Section 7 consultation with the FWS.

59. The FWS disagrees. The range projected by Strayer (1991) using mean annual temperatures includes all but a fraction of southeastern Oklahoma. Conductivity and hardness in southeast Oklahoma are sufficient for mussels and gastropods to thrive across the area. The most likely routes of invasion involve placement of contaminated watercraft into reservoirs; for these and many of the tributary streams, salinity is not excessive.

60. The Endangered Species Act, specifically Section 7(a)(2), requires federal agencies to consult with the FWS whenever actions they perform may affect a listed species. Because operation of Sardis Reservoir has a recognized potential to affect the Ouachita rock pocketbook, the CE and FWS have initiated informal consultation regarding that operation. This consultation is being performed under standard procedures for interagency consultation detailed in 50 CFR 402.

61. Past and present research activities have provided a progressive increase in knowledge regarding the Ouachita rock pocketbook's habitat requirements and potential limiting factors. Future research will extend that knowledge. While knowledge remains incomplete, protection efforts can focus on known problems (e.g., mussel strandings below dams, specific sources observed as degrading water quality) and researched subjects (e.g., habitat associations in the Kiamichi River). As knowledge increases, it may modify initial priorities, or concepts of what constitutes sufficient protection for the species.

<u>David P. Flemming, FWS, Region 4</u>

62. Previous references to "upgrading" the species to threatened status have been replaced by "reclassification of," as requested. The FWS office primarily responsible for the plan preferred the former term at the time the draft was prepared, to express the positive nature of potentially improving a species' status from endangered to threatened. Currently that office agrees with use of the term reclassification, particularly for reasons of promoting a single, uniform terminology throughout the FWS recovery program. In addition, the lead office believes a relatively good chance exists to see Tuskahoma Reservoir deauthorized.

63. The suggested changes were made, along with an updating of the information.

64. Identification of deauthorization as a reasonable and prudent alternative (i.e., a protective action possible under existing law) might be difficult, because alone it would fail to serve the purposes of the reservoir project.

65. This refers basically to events such as accidental spills of deleterious materials. The sentence has been clarified.

66. The suggested change has been made.

67. Examples of additional measures include actions identified in the subordinate subtasks, i.e., 1.21 through 1.25. Examples of limited authorizations are identified in the same subtasks, or should be fairly apparent. While development of a habitat conservation plan is required in an instance of take, implementation of conservation measures that avoid take can be done voluntarily. The latter also have greater flexibility in their specific form and in participating parties.

68. The FWS office primarily responsible for the recovery plan prefers to retain the original language. While deauthorization of the project would represent a tangible benefit to the species, evaluating the feasibility of deauthorizing the project would not necessarily produce a benefit of similar importance.

69. The AZAA and Contractor (unspecified) have been added to the lists for these tasks. The FWS considers universities to qualify for the latter category.

70. The suggested change has been made.

Mark D. Howery, Oklahoma Department of Wildlife Conservation

71. No summary response needed.

Anthony F. Maciorowski, U.S. Environmental Protection Agency

72. No summary response needed.

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